SEMI-ANNUAL REPORT

NASA CONTRACT NAS 5-31368

For
MODIS Team Member: Steven W. Running
Assoc. Team Member: Ramakrishna R. Nemani
Software Engineer: Petr Votava
Subcontractor: Joe Glassy

15 July 2003

OBJECTIVES:

We have defined the following near-term objectives for our MODIS contract:

- Test software for our MODIS products, #15 Leaf Area Index and Fraction Absorbed Photosynthetically Active Radiation, #16 Evapotranspiration from land surface, and #17 Daily Photosynthesis Annual Net Primary Production as MODAPS processing delivers global datasets.

- Deliver software for the Aqua MODIS sensor, for MOD 15, MOD 17 and the new MOD 16, Surface Evaporation Index

- Develop MODIS applications products for national natural resource management.

- Organization of a validation effort using AMERIFLUX fluxnet sites to correlate and test the MODIS derived LAI and Net Primary Production.

The NTSG lab currently employs:

Dr. Steven Running, Director and Professor,
Dr. Ramakrishna Nemani, Research Assoc. Professor
Dr. John Kimball, Research Assistant Professor
Dr. Sinkyu Kang, Postdoctoral Research Associate
Dr. Maosheng Zhao, Postdoctoral Research Associate
Dr. Faith Ann Heinsch, Postdoctoral Research Associate
Mr. Petr Votava, Software Engineer
Mr. Chad Bowker, Programmer
Mr. Andrew Neuschwander, Programmer/Sys Admin
Mr. Saxon Holbrook, Computer Systems Engineer
Mr. Andy Michealis (Student Programmer)

Mr. Matt Reeves, PhD student
Mr. W. Matt Jolly, PhD student
Ms. Pat Andrews, PhD student
Ms. Rachel Loehman, PhD student
Ms. Cristina Milesi, PhD student
Ms. Ann Radil, MS student
Ms. Alana Oakins, MS Student
Mr. David Mildrexler, MS Student
Ms. Youngee Cho, Office Manager

All of these members contribute to certain aspects of our MODIS work.

ACITIVITES OF Steven W. Running, Principal Investigator

For most of this period I was a Visiting McMaster Fellow with the CSIRO Division of Land and Water in Canberra Australia. The purpose of my trip was to improve validation and application activities of our MODIS datasets. I was hosted by the director of the Ozflux network, Dr. Ray Leuning, where our focus was fluxtower validation of MODIS GPP data. I also worked with Dr. Alex Held on MODIS Fire Danger applications of our MOD16 data. I also worked with DR. Michael Raupach of the Earth Observation Center in Canberra, ACT.

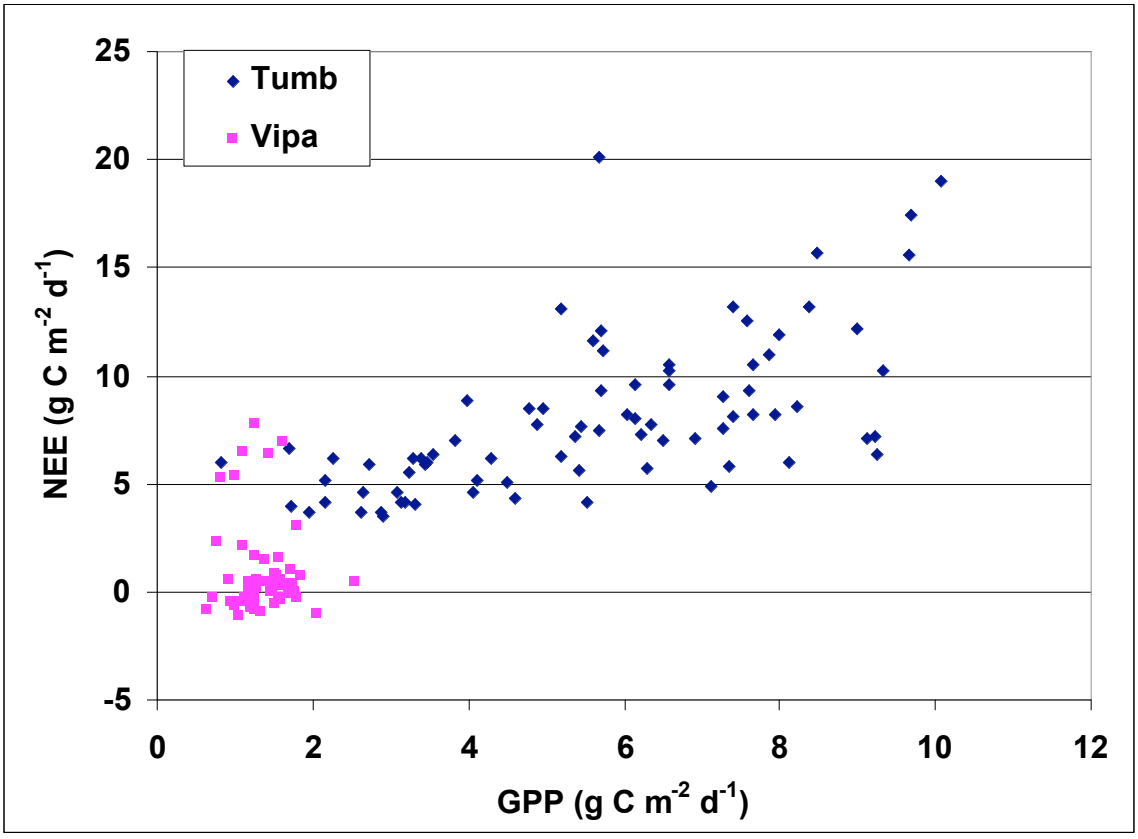
An overall objective of my sabbatical visit was to develop research coordination with CSIRO scientists for use of the new Earth Observing System data from the MODIS, Moderate Resolution Imaging Spectroradiometer, launched in Dec 1999. This satellite represents the new generation of polar-orbitiing Earth Observation satellites for terrestrial research and land management applications. The research at CSIRO was meant to provide CSIRO scientists with the latest datasets from this new satellite, and begin validation activities to judge the relevance of this satellite for Australian science and land management. A good general summary of these datasets is available in a new NASA Press Release at:

http://earthobservatory.nasa.gov/Newsroom/NPP/ .

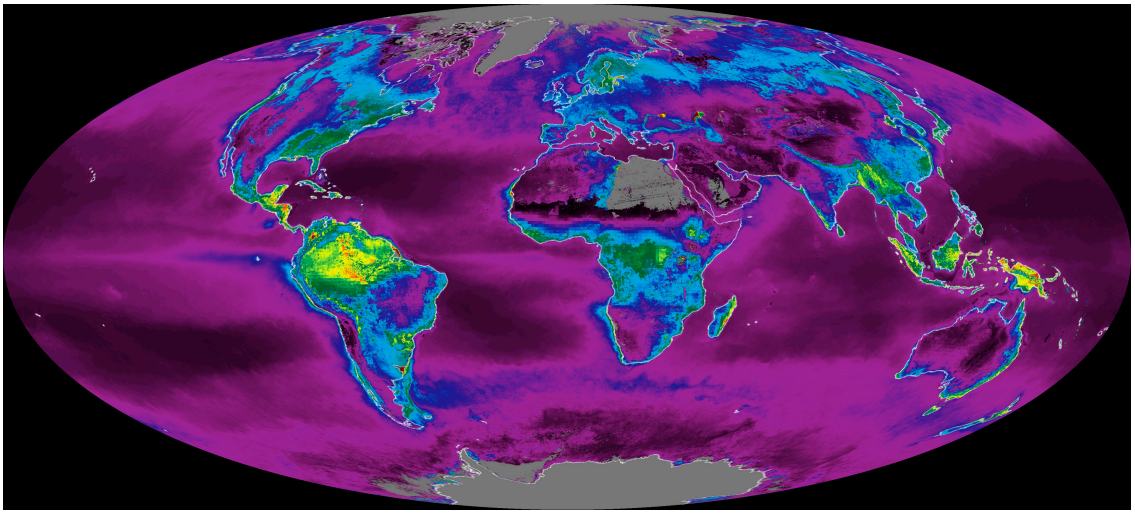
I am responsible for three research products from MODIS relevant to terrestrial science, an 8-day Gross Primary Production (GPP), a yearly Net Primary Production (NPP), and an 8-day Evaporative Index (EI). The 8-day GPP is most useful for quantifying vegetation growing seasons, with applications for grazing management and agricultural monitoring. The annual NPP best measures the carbon source/sink strength of large areas, with greatest relevance for national and global carbon cycle science. The EI infers energy budget partitioning to latent/sensible heat, and has applications for Drought and Fire Danger monitoring.

My ongoing research with CSIRO scientists encompasses four activities. These activities are all ongoing, and both formal publications and development of enhanced satellite datasets for Australia will be the result.

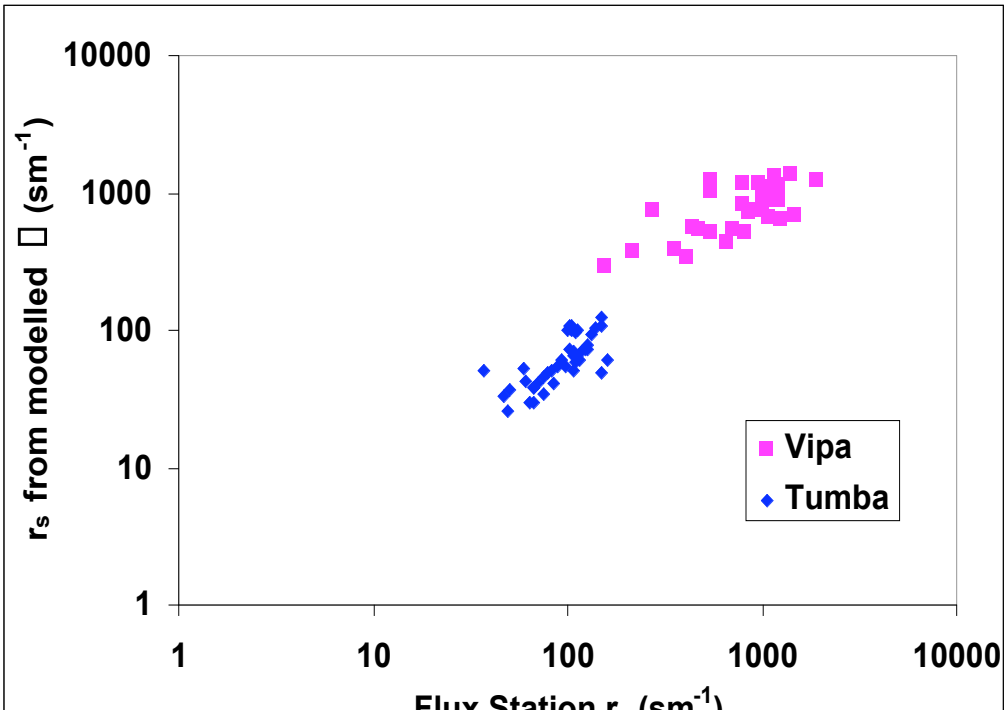
1. I have provided Drs Leuning and Cleugh with MODIS data at 8-day intervals for 2001 and 2002 for the Howard Springs, Mackay, Uardry, Tumbarumba, Tinga Tingana, Daintree, Virgina Park and Janina research sites. We have initiated detailed validation studies on the Tumbaraumba and Virginia Park sites where eddy co-variance flux towers necessary to this validation logic are installed and operating. We are testing the daily gross primary production measured by MODIS against the net ecosystem carbon exchange measured by the flux towers. The following graph is an example of the analysis we are doing.



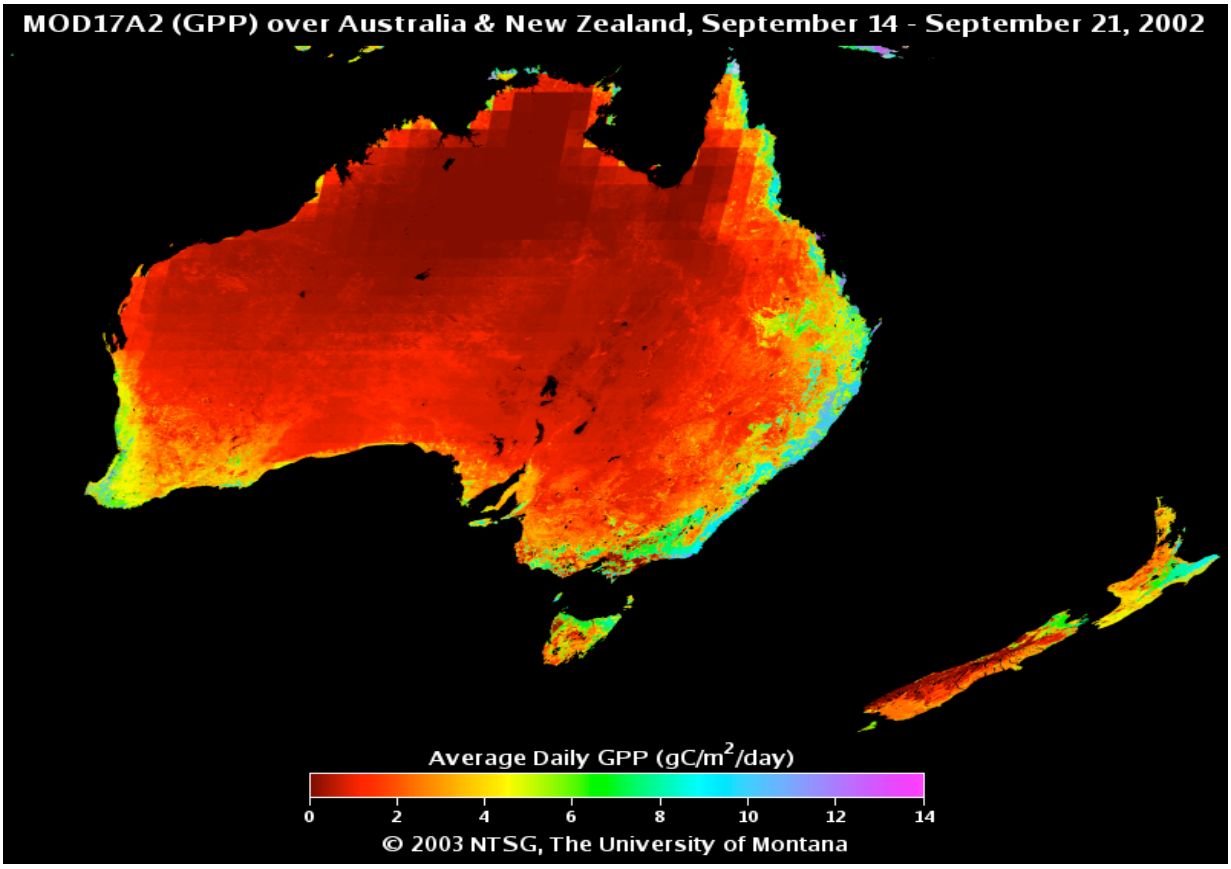
2. I have provided global annual Net Primary Production data from MODIS for 2001 and 2002 to Dr. Ying Ping Wang of CAR, and Damien Barrett of the Pye Lab for validation research. We are progressing on comparing the annual NPP for Australia from Barrett and Wangs dataset with the MODIS annual NPP for the continent. The global NPP image for 2002 is shown below.



3. Drs Leuning, Cleugh and myself are continuing development of an Evaporative Index algorithm for the MODIS satellite. We are computing the surface evaporative resistance, as measured by the fluxtowers and the MODIS satellite. The graph below shows our current analysis for this index, which will have significant applications for Drought and Fire Danger mapping when complete.



4. I am continuing work with Drs Mike Raupach and Alex Held at the Earth Observation Centre to streamline the ongoing delivery of EOS data, and particularly MODIS Atmospheric, land and ocean data to Australia, and to improve efficiency of processing.



I have given seminars at the following CSIRO Research Divisions:

Land and Water, Black Mtn, Canberra, February 3, 2003
Marine Research, Hobart, Feb 13, 2003
Land and Water, Pye Lab, Feb 20, 2003
Earth Observation Center Annual Meeting, Feb 24, 2003
Land and Water, Black Mtn Canberra, April 23, 2003
Atmospheric Research, Aspendale, April 11, 2003
Floreat Lab, Perth, April 29, 2003
Land and Water, Earth Observation Center, Canberra May 2, 2003

8th Annual The Community Climate System Model (CCSM) Workshop, Breckenridge, CO, June 2003
Committee on Environmental Satellite Data Utilization (CESDU) Meeting , Madison, WI June 2003
NASA/North America Carbon Program Joint PI Meeting, Washington DC, May 2003
NASA/Carbon Cycle SSG meeting, Washington DC, May 2003
CEOS WGCV's 20th plenary meeting, Hobart Australia, February 2003

ACTIVITIES of Ramakrishna Nemani (Associate Team Member)

MODIS Net primary production (MOD17)

Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999.
Ramakrishna R. Nemani, Charles D. Keeling, Hirofumi Hashimoto, William M. Jolly, Stephen C. Piper, Compton J. Tucker, Ranga B. Myneni, Steven W. Running. Science, 300, 1560, 2003 (June 6th)

Recent climatic changes have enhanced plant growth in northern mid-latitudes and high latitudes. However, a comprehensive analysis of the impact of global climatic changes on vegetation productivity has not before been expressed in the context of variable limiting factors to plant growth. We present a global investigation of vegetation responses to climatic changes by analyzing 18 years (1982 to 1999) of both climatic data and satellite observations of vegetation activity. Our results indicate that global changes in climate have eased several critical climatic constraints to plant growth, such that net primary production increased 6% (3.4 petagrams of carbon over 18 years) globally. The largest increase was in tropical ecosystems. Amazon rain forests accounted for 42% of the global increase in net primary production, owing mainly to decreased cloud cover and the resulting increase in solar radiation.

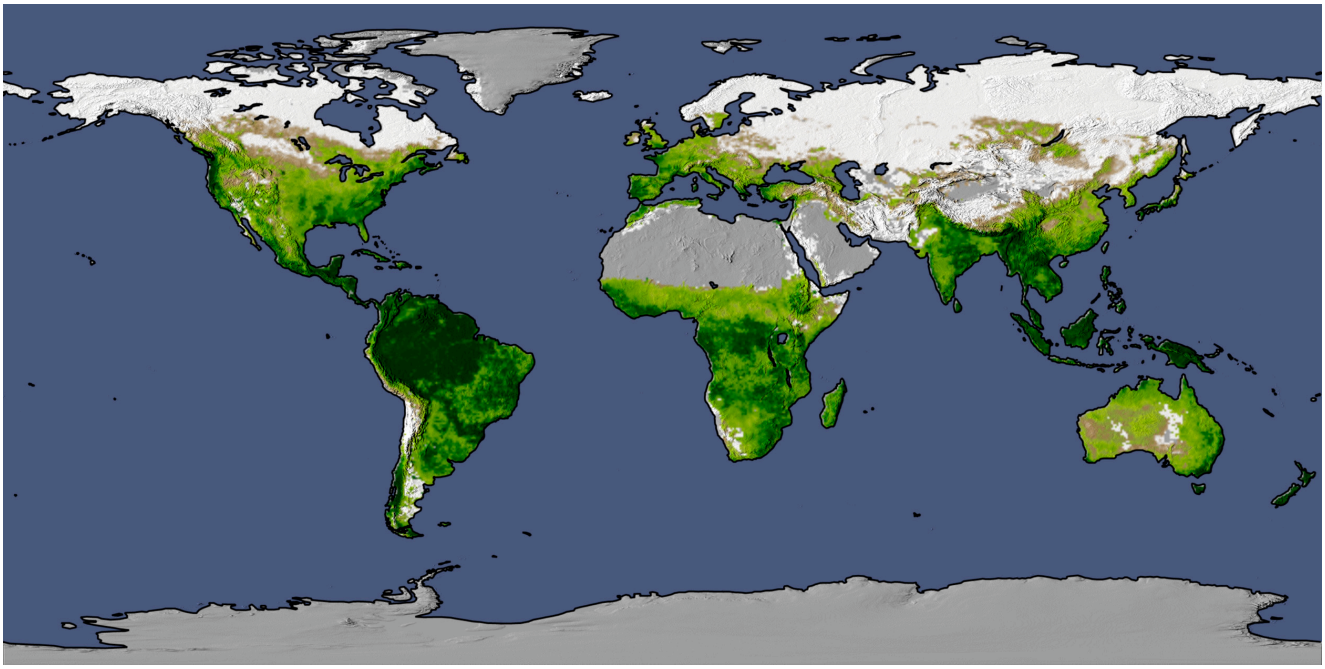


Figure 1. Global NPP for 1999. (from Nemani et al 2003.)

Fig 1: Spatial distribution of changes in NPP between 1982 and 1999.

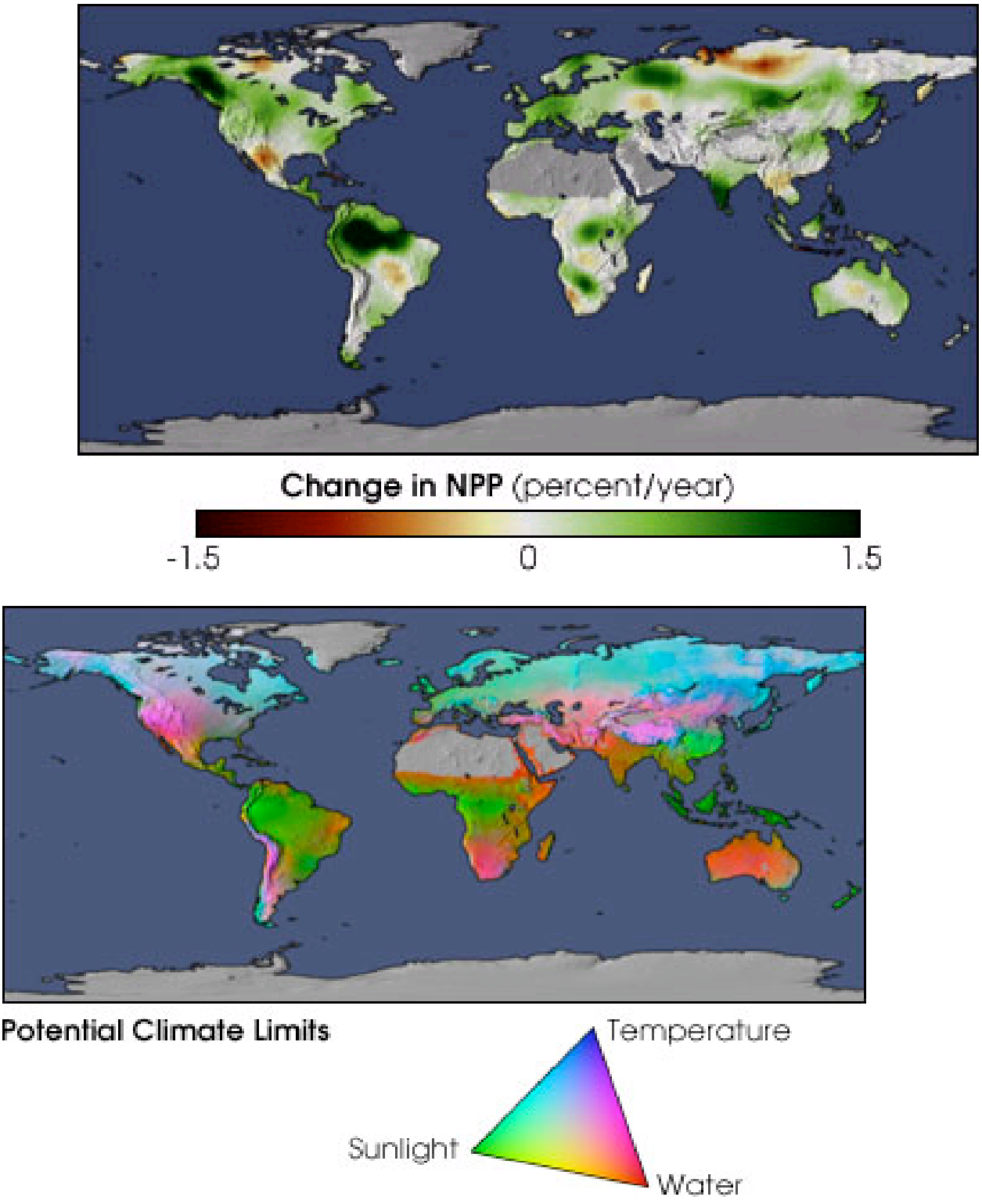


Fig. 2. This image shows our analysis of the relative controls of the primary climatic factors temperature, radiation and water in limiting global NPP. (from Nemani et al 2003).

MEETINGS ATTENDED

AGU FALL meeting, December 2002

PUBLICATIONS:

Nishida, K., R.R. **Nemani**, S.W. Running and J. Glassy. 2003. An Evapotranspiration Index from Aqua/MODIS for monitoring surface moisture status. *IEEE Transactions on Geoscience and Remote Sensing*, 41(2): 493-501.

Nishida, K., R.R. **Nemani,** S.W. Running and J. Glassy. 2003. Remote sensing of land surface evaporation: Theoretical basis for an operational algorithm. *Journal of Geophysical Research* VOL. 108, NO. D9, 4270, doi:10.1029/2002JD002062, 2003

Johnson, L., D. Roczen, S. Youkhana, R.R. **Nemani** and D.F. Bosch. 2003. Mapping vineyard leaf area with multispectral satellite imagery. Computers & Agriculture, 38(1): 37-48.

White, M.A., and R.R. Nemani. 2003. Canopy duration has little effect on annual carbon storage in the eastern United States broadleaf forest. Global Change Biology, 9(7), 967-1968.

Nemani, R.R., M.A. White, Lars Pierce, Petr Votava, Joseph Coughlan and S.W. Running. 2003. Biospheric monitoring and ecological forecasting, Earth Observation Magazine, 12 (2): 6-8.

Nemani, R.R., C.D. Keeling, H. Hashimoto, M. Jolly, S. Piper, C.J. Tucker, R. Myneni and S. Running. 2003. Climate-driven increases in global terrestrial net primary production from 1982 to 1999, Science 300, 1650 (2003).

ACTIVITIES OF M. Zhao (Postdoctoral Researcher)

1. Correct MOD17 NASA source code

I have found several critic bugs in NASA MOD17 (PGE36) and asked software engineer to correct them. This made MOD17 products are free of problem from source codes.

2. Cutout programs for MODIS validation

I have written and updated cutout C programs which can deal with MOD11A2, MOD12Q1, MOD13A2, MOD15A2, MOD17A2, MOD17A3 and DAO to support MODIS validation work in our lad and outside. These programs are easy to use. Although ORNL provides cutout, the work of dealing with these data becomes difficult for users because of the uncertainties of location of flux tower, complex format of data it provides, and troublesome quality control (QC).

3. DAO validation

MOD17 is very sensitive to meteorological inputs, and it is vital to know the uncertainties arising from assimilation meteorological data set (DAO) with coarse spatial resolution. To investigate this, I have chose more than 5000 global weather stations from more than 7000 with criterion of few missing daily records to validate DAO and NCEP, another well-known assimilation meteorological data set. Fig. 1 shows the results of comparison of annual average of temperature and VPD between DAO and observed. It reveals that DAO VPD contains more uncertainties than Tavg, and lower latitude has more uncertainties than higher latitude.

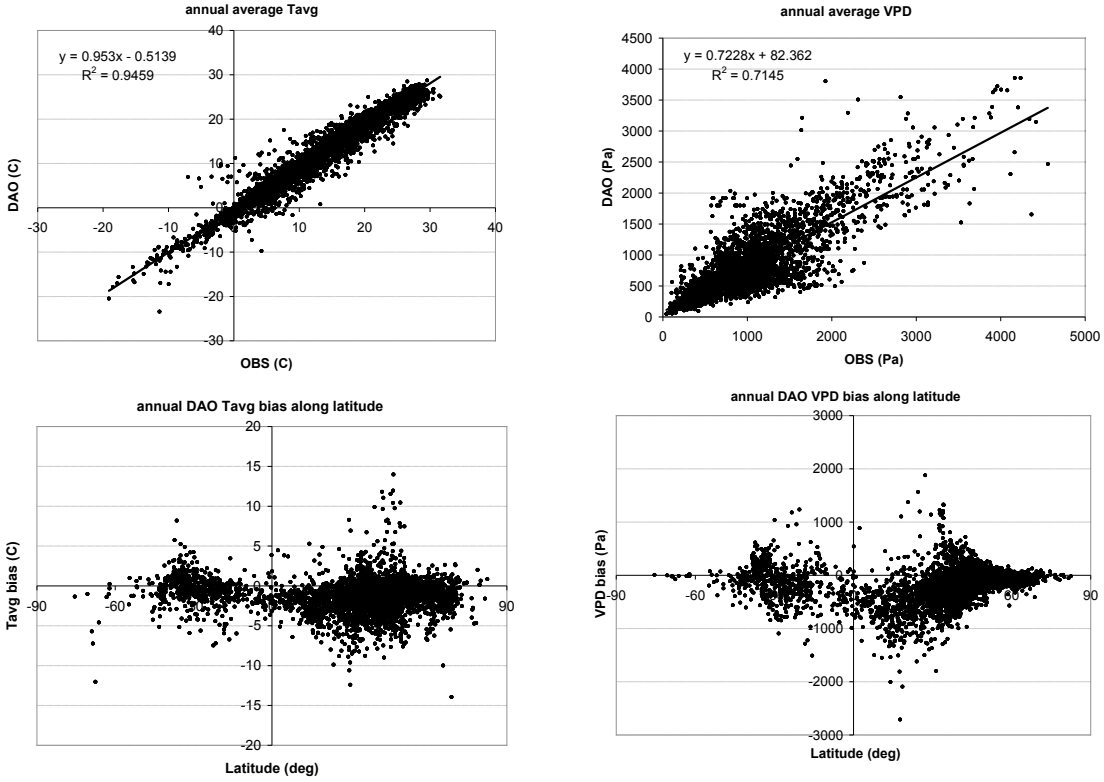
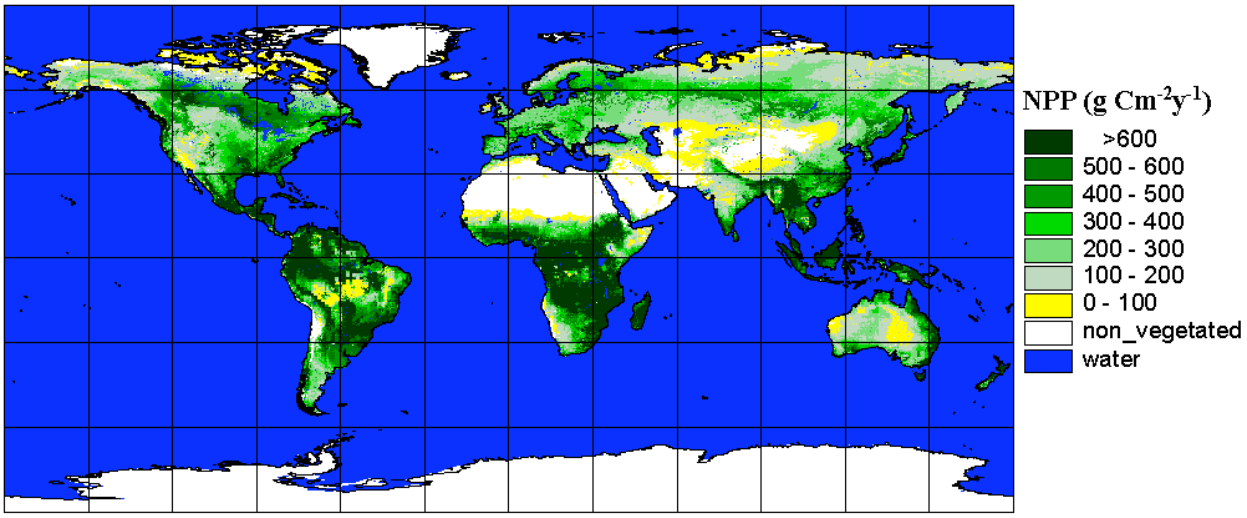


Fig. 1, validation of DAO average temperature and VPD

4. Inhouse MOD17 source code

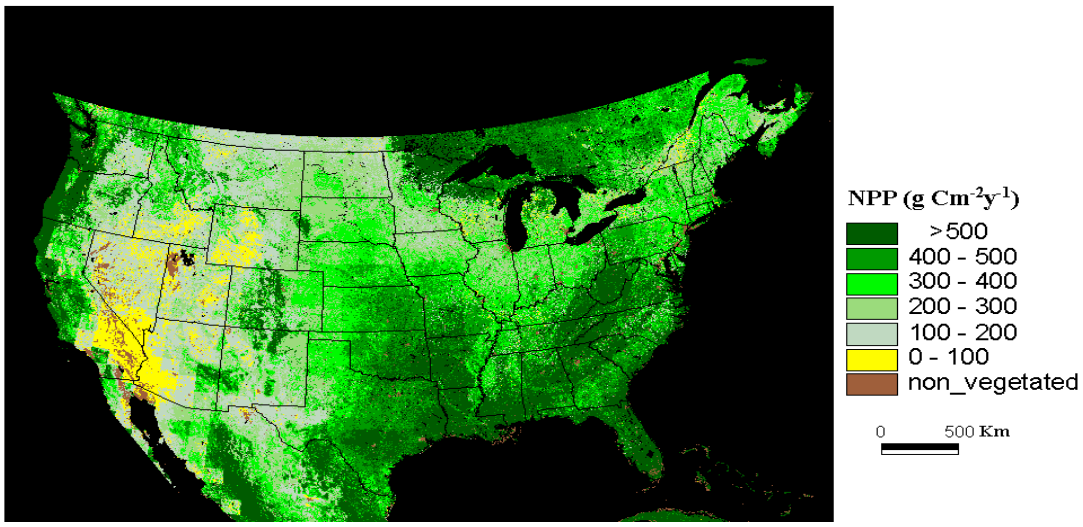
Currently, NASA MOD17 source code (PGE36) can not deal with the missing periods of MODIS data, which cause unreliable annual GPP & NPP (MOD17A3) because PGE36 leaves non-data periods. I have written an inhouse MOD17 source code which can linearly fill the missing periods of upstream inputs such as 8-day MOD15A2 and daily DAO to produce 'complete' MOD17A3. These results will be provided to NASA as standard MOD17A3 to allow users to get 'complete' MODIS NPP.

This figure is the latest test of the MOD17 annual NPP with Corrected collection 4 data.



5. Timely monitoring MOD15, DAO and MOD17 version changes

I have found that new version of daily DAO data set (GEOS402) eliminated its early version problems (higher temperature, higher VPD) over large part of tropical regions. This has resulted in reasonable NPP values over tropical regions compared to huge negative MODIS NPP in the past arising from old version DAO. Also collection4 MOD15A2 has improved its result. I found that higher collection3 LAI for closed shrub lands, woody savanna, savannas, grasslands and croplands has dropped in collection4 by examining histogram of maximum LAI for different vegetation types. These improvements of DAO and MOD15A2 will improve MOD17 products in the end (fig. 2).



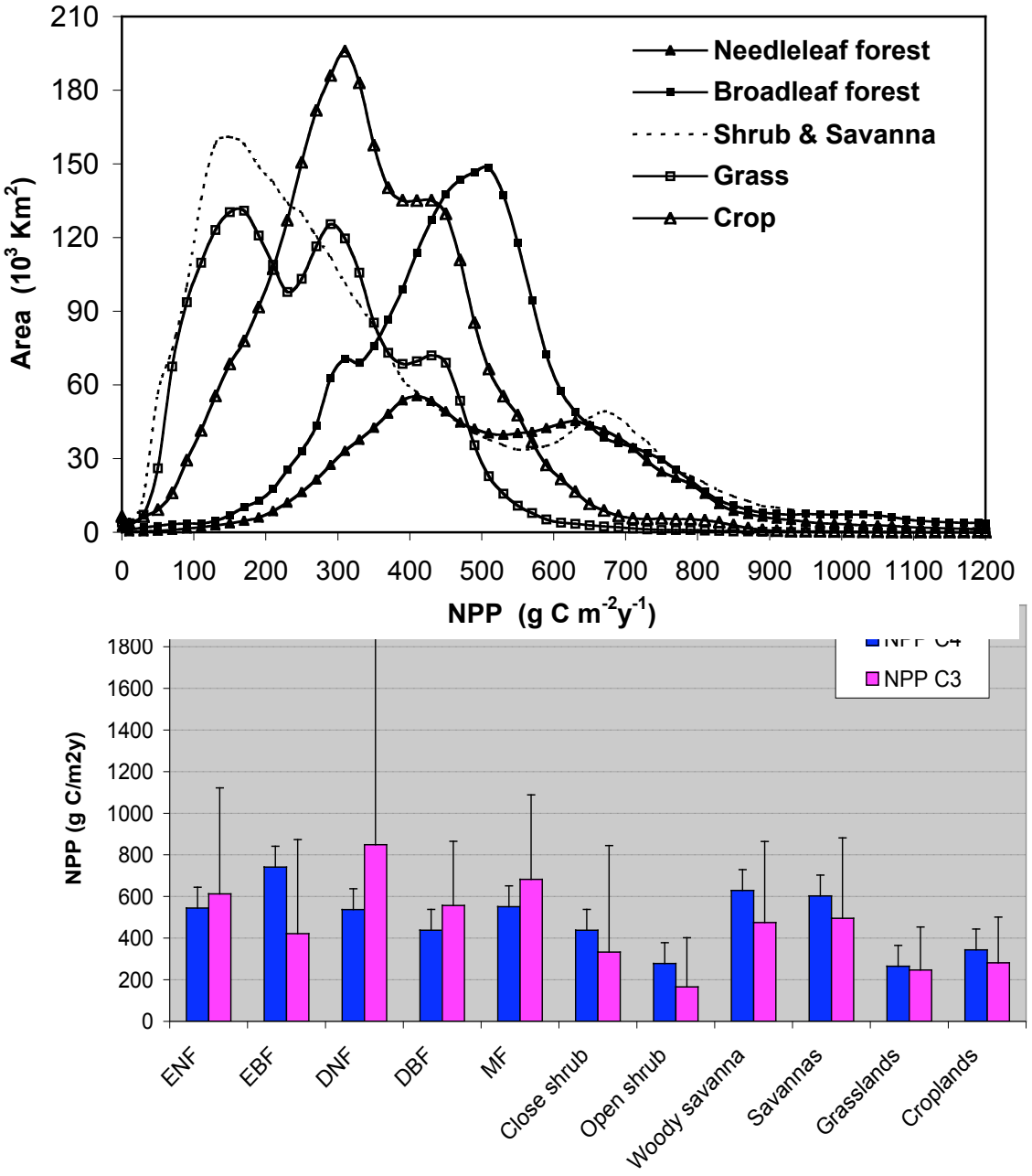


Fig. 2, comparison of collection4 and collection3 MODIS NPP over USA

6. Fine resolution meteorological data (SOGS) run MOD17

I have finished a program which can run MOD17 with higher resolution meteorological data set named SOGS (previously, named Daymet, see http://www.daymet.org/). This MOD17 has higher reliability at local scale and can be used in natural resource management, such as wheat and grass yield, etc.

7. Pan-arctic carbon cycle (with John Kimball)

Using 25km RIMS/NCEP data set(http://rims.unh.edu/data/data.cgi) and 16km AVHRR FPAR/LAI from 1982 to 2000 to study Pan-Arctic region NPP interannual variations, and combining SSM/I thaw timing, we want to study which factors influence NPP over this polar region. The preliminary results reveal that growing season length plays a dominant role in determining NPP variation. Cloud cover, however, is of importance in some regions.

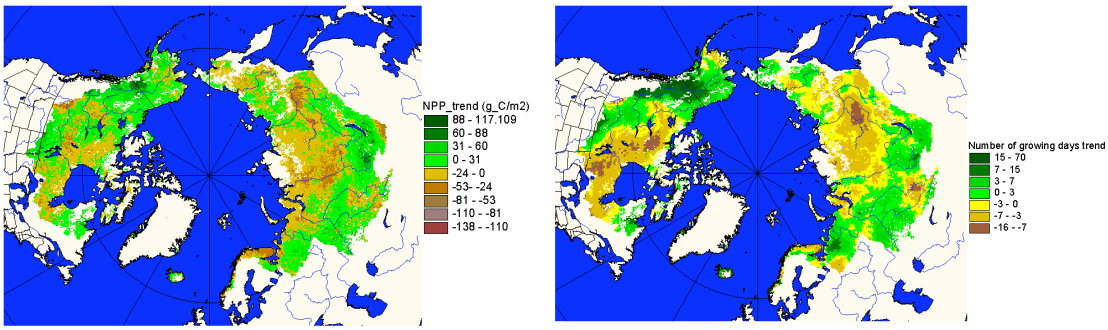


Fig. 3. AVHRR NPP trend based on MOD17 algorithm and growing days trends on Pan-Artic region

Presentation:

1, "DAO validation", Zhao M., presented at the MODIS Vegetation workshop, Missoula, MT, July 15,2002

2. "Sensitivity analysis of MOD17 to MOD15 input " , Zhao M., R. Nemani, S. W. Running, S. Kang , poster at the MODIS Vegetation workshop, Missoula, MT, July 15,2002

3 "Sensitivity of MODIS derived photosynthesis and net primary productivity to relative accuracy of meteorological inputs", Zhao M., W. M. Jolly, J. S. Kimball, R. Nemani, S. W. Running, S. Kang, presented at ESA meeting, Tucson, AZ, August 4, 2002

4. "MODIS 17 NPP sensitivity analysis and validation", Zhao M., R. R. Nemani, S.W. Running, J.S. Kimball, S. Kang, IARC meeting, Honolulu, HI, Oct 15-17, 2002

5. "Validation of the MODIS MOD17 Algorithms for Estimating global Net Primary Production", Zhao M., S. W. Running, R. R. Nemani, J. S. Kimball, S. Kang, AGU fall meeting, San Francisco, CA, Dec 6-10, 2002

Paper:

Maosheng Zhao, S. Kang, R. R. Nemani and S. W. Running, Evaluation of MODIS Gross and Net Primary Productivity Products (MOD17) for 2001 and 2002. (in preparation)

Summary:

During the past year, much work has been done to develop relationships with researchers participating in the AmeriFlux network (http://public.ornl.gov/ameriflux/Participants/Sites/Map/index.cfm) for the purposes of MODIS gross primary productivity (GPP; MOD17A2) validation. Currently there are thirteen participating sites, all of which have provided flux tower-based meteorological data and GPP estimates for 2001. The most recent comparisons, created using an off-line version of the MOD17A2 algorithm, include both the MOD15A2 LAI/fPAR estimates from Collection 4 and the most recent version of the DAO data (GEOS402). General results (Figure 1) indicate that the MOD17A2 algorithm overestimates GPP for most biomes. While the use of tower meteorology in the MOD17A2 algorithm improves the offset bias of algorithm GPP estimates, it does not improve deviation from mean (Figure 2). Preliminary analysis indicates the overestimation arises from the use of the DAO meteorology, in particular, the vapor pressure deficit (VPD). The DAO input data consistently underestimates actual VPD in drier regions (Figure 3), resulting in the overestimation of GPP in these areas. Additional error is associated with MOD15A2 Lai/Fpar inputs, primarily resulting from cloud contamination. Future work will include the addition of more sites to the validation effort, as well as the impact of using a cloud-filling algorithm (Kang et al., in review?) to improve the MOD15A2 input data. The sensitivity of the algorithm to the seasonality of the MOD15A2 will also be explored, particularly for evergreen sites.

Conferences:

AmeriFlux Annual Meeting, Boulder, CO., 10-14 October 2002

Heinsch, FA, AJ Oakins, M Zhao, SW Running. "MOD17A2 (MODIS GPP) Output for Active Ameriflux Sites" at the Ameriflux Science Meeting, October, 2002.

Running, SW and FA Heinsch. "MODIS Validation and Real-Time Modeling" at the Ameriflux Science Meeting, October, 2002.

AGU Fall Meeting, San Francisco, CA., 6-10 December 2002

Heinsch, FA, JS Kimball, AJ Oakins, M Zhao, S Kang, RR Nemani, SW Running. "Intercomparison of MODIS and Tower Eddy Flux-based Estimates of Gross Primary Production" at the American Geophysical Union Meeting, San Francisco, CA, December 2002.

ChEAS Annual Meeting, Minoqua, WI., 29 June – 2 July 2003

Heinsch, FA. "Use of Biome-BGC with the ChEAS flux tower network to address scaling issues"

FluxNet Mini Workshop, Tahoe City, CA., 11-14 August 2003

Heinsch, FA and SW Running. "MODIS GPP, NPP and LAI: What is being done?

Figure 1. Comparison of MODIS GPP estimates from the MOD17A2 algorithm with flux tower estimates of GPP using the official MOD15A2 (Collection 4) and DAO (GEOS402) inputs.

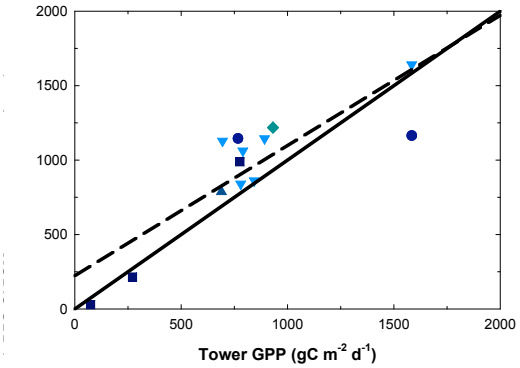


Figure 2. Comparison of MODIS GPP estimates from the MOD17A2 algorithm using tower meteorology as an input.

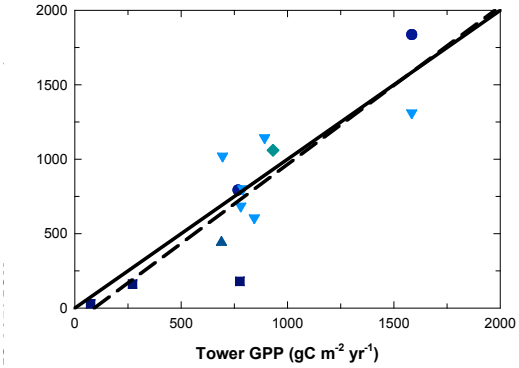
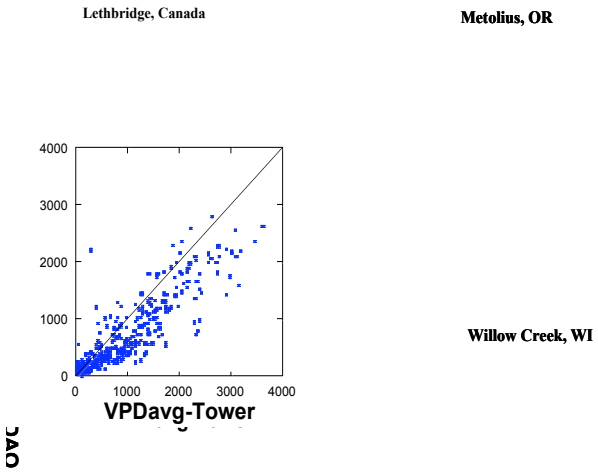


Figure 3. Comparison of vapor pressure deficit between the DAO GEOS402 data and tower meteorology at various AmeriFlux network site.



ACTIVITIES OF Sinkyu KANG (Postdoctoral Researcher)

1. Post processing

The Moderate Imaging Spectroradiometer (MODIS) sensors onboard the NASA Terra and Aqua satellites provide the means for frequent measurement and monitoring of the status and seasonal variability in global vegetation phenology and productivity. However, while MODIS reflectance data is often interrupted by clouds, terrestrial processes like photosynthesis are continuous, so the MODIS photosynthesis data must devise ways to cope with cloudy pixels. We examined the effect of clouds on the MODIS photosynthesis product (PSNnet) by proposing three alternative cloud-correction algorithms, which have different levels of complexity and correct errors associated with cloudy-pixel surface reflectance. Our results indicate that the proposed cloud correction methods improve the current MODIS PSNnet product considerably at both site and regional scales and weekly to annual time steps for areas subjected to frequent cloud cover. The corrections can be applied as a post-processing interpolation of PSNnet, and do not require reprocessing of the MOD17A2 algorithm. As the MOD17 algorithm development team, the Numerical Terradynamic Simulation Group (NTSG) at the University of Montana will provide these post-processing cloud-correction tools for MOD15/17 users. In the future, we will attempt to provide cloud-corrected MODIS productivity data as a post-processing enhanced dataset from our lab server.

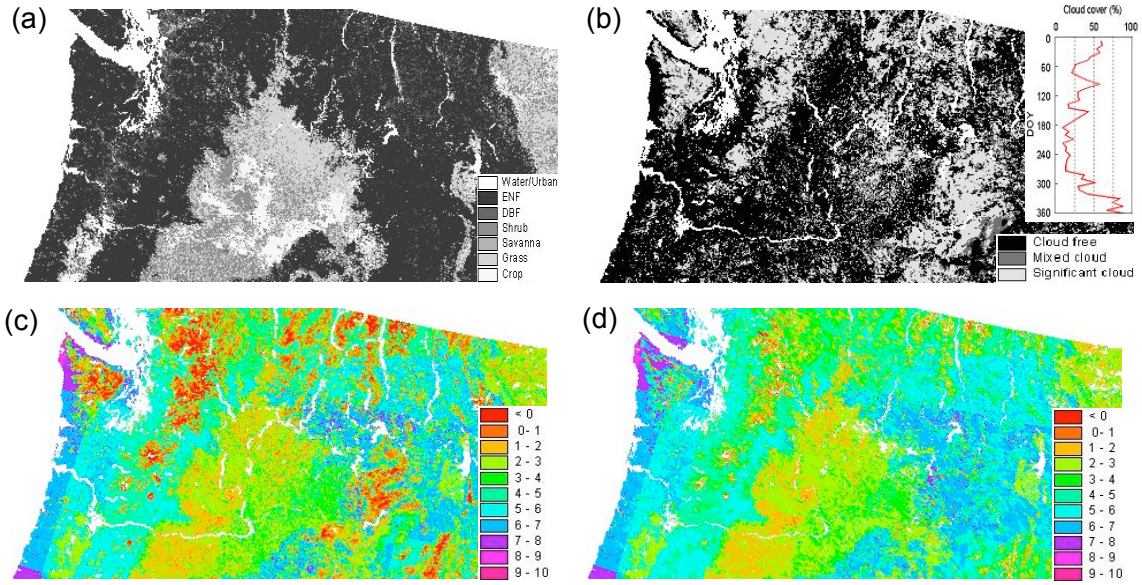


Figure. Landcover and PSNnet of the Pacific Northwest (PNW) U.S.A. study region (1,000km×500km): (a) landcover; (b) MOD17A2 QC for a period of 153-160 DOY; (c) standard MOD17A2 PSNnet for the same period; (d) cloud corrected PSNnet using the PSN-rerun algorithm. An imbedded graph in (b) shows seasonal variation of cloud cover fraction in the PNW.

2. Regional phenology model

A regional phenology model for detecting onset of vegetation greenness was developed using year 2001MODIS land products in temperate mixed forests in Korea. The model incorporates a digital elevation model (DEM), Moderate Resolution Imaging Spectroradiometer (MODIS) Landcover and Leaf Area Index (LAI) products, and climate data from weather monitoring stations. MODIS-based onset of greenness varied spatially and showed significant correlation with air temperature ($r = -0.70$, $p<0.001$). Our modeling methodology is to relate thermal summation calculated using the MODIS-based timing of onset with 30-year mean air temperature. Onset of greenness is expected to occur at values above the critical thermal summation threshold, and is predicted to vary spatially. An algorithm for downscaling eight-day composite MODIS LAI product to a daily unit was introduced and its predictability was validated using ground-measured onset of greenness. Two unknown parameters and the best regression were determined by iterative cross-validation. Minimal cross-validation errors between the predicted and MODIS-based timings of onset were found at a mean absolute error (3.0 days) and bias (+1.6 days). The predicted onsets show good agreement with ground-measured onset of greenness (MAE = 2.5 and bias = +2.5 days). This study demonstrates the utility of MODIS Land products as tools for detecting spatial variability in phenology across climate gradients.

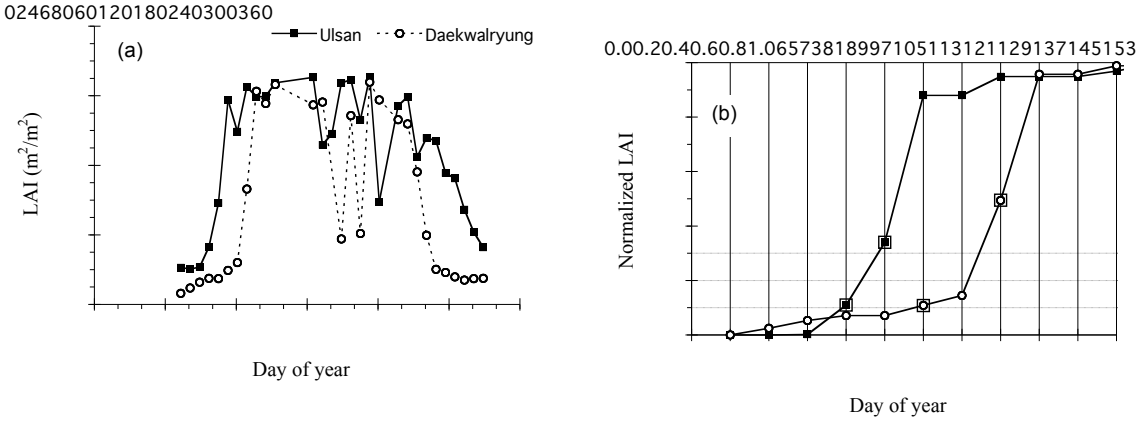


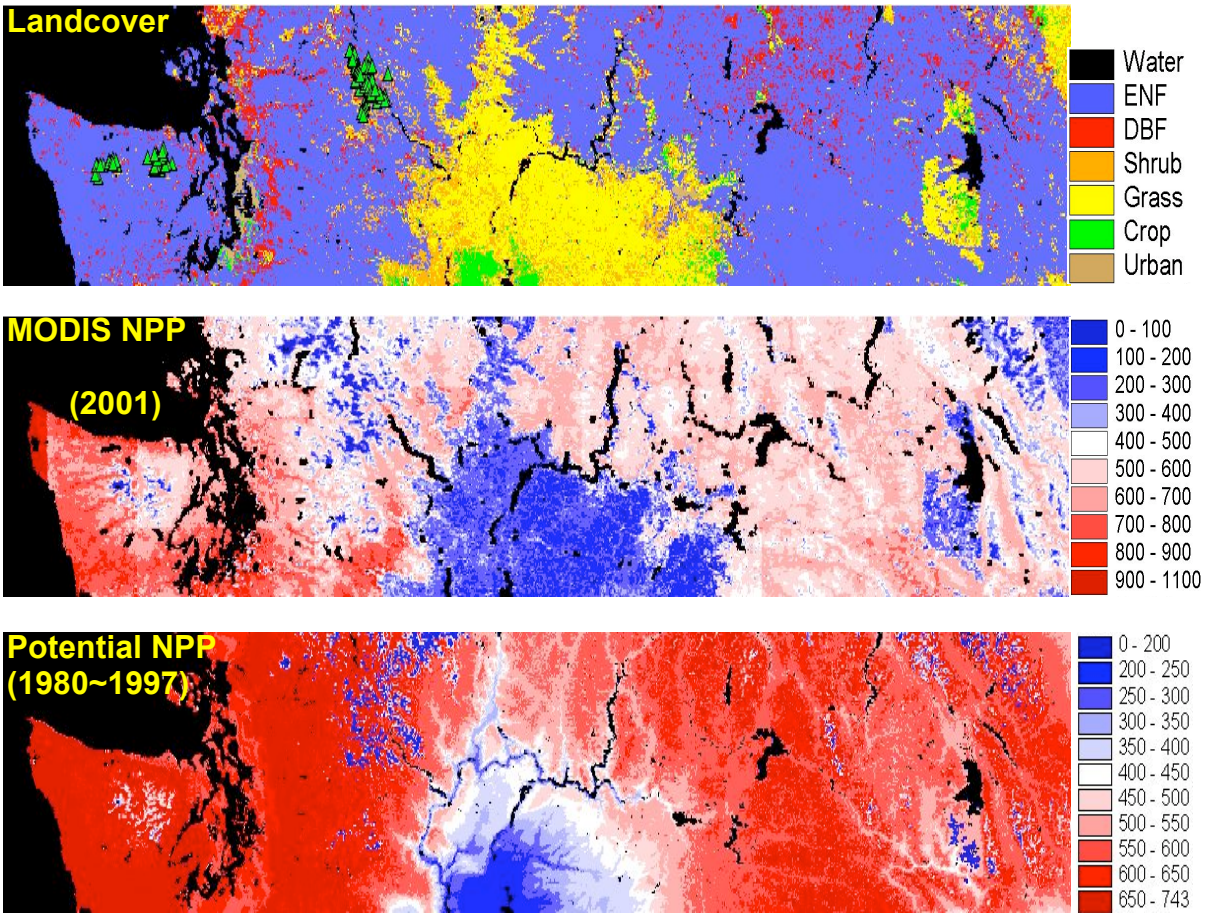
Figure. Sample time series of (a) MODIS LAI and (b) normalized LAI from Ulsan and Daekwalryung sites. Dashed horizontal lines in (b) are different onset thresholds ($LAI_{n,C}$) applied in this study. Open rectangles represent timing of onset chosen depending on the different thresholds.

3. Comparisons of MODIS productivity and potential productivity in Pacific Northwest and BOREAS area.

MODIS annual productivity (GPP & NPP) in 2001 was compared with the potential productivity predicted by BIOME-BGC in PNW and BOREAS areas. BIOME-BGC was calibrated with field measurements of LAI and fluxtower measurements of old forest sites in the both area. A gridded BIOME-BGC simulation was conducted using Daymet daily meteorological data (1km□1km resolution) and BOREAS Follow-On MOD-01 Regional Daily Averaged Gridded Meteorological Data (10'□5' resolution) in the PNW and BOREAS areas,

respectively. Spatial patterns of MODIS productivity in 2001 and mean potential productivity (PNW: 18 years & BOREAS: 3 years) were compared with each other. The potential forest is similar to the old forest in terms of maximum LAI and seasonal NEE and ET. ENF and DBF showed higher productivity than Shrub and Grass biomes in both potential and MODIS productivity. In the BOREAS area, MODIS NPP is higher than potential NPP in spite of similar GPP. MODIS NPP is spatially more variable than potential NPP. Landcover explains the distinct spatial variation of productivity across different biomes but local topography seems to produce spatially variable productivity within a homogeneous landcover. In general, MODIS NPP is lower than potential NPP at higher elevations but higher or equivalent at lower elevations.

Figure. Examples of MODIS 1km Landcover and NPP (gC m^{-2} y^{-1}), and spatial BIOME-BGC modeling in Pacific Northwest.



Publications

Lee, D., Yook, K.H., Lee, D., Kang, S., Kang, H., Lim, J.H., Lee, K.H. 2002. Changes in annual CO_2 fluxes estimated from inventory data in South Korea. Science in China, 45, 87-96.

Sinkyu Kang, Steve W. Running, Jong-Hwan Lim, Maosheng Zhao, Chandra Park, Rachel Loemann (2003) A Regional Phenology Model for Detecting Onset of Greenness in Temperate Mixed Forests, Korea: An Application of MODIS Leaf Area Index (LAI). Remote Sensing of Environment, 86, 232-242.

Kang, S., D. Lee, J.S. Kimball. The effects of spatial aggregation of complex topography on hydro-ecological process simulations within a rugged forest landscape: Development and application of a satellite-based topoclimatic model. Canadian Journal of Forest Research (in press).

Kang, S., Doh, S., Lee, D.S., Lee, D., Jin, V., Kimball, J.S. 2003. Topographic and Climatic Constraints on Soil Respiration in Temperate Mixed-Hardwood Forests in Korea. Global Change Biology (in press).

Sinkyu Kang, Steve W. Running, Maosheng Zhao, John S. Kimball, Joeseph Glassy (2003). Improving continuity of MODIS terrestrial photosynthesis products using an interpolation scheme for cloudy pixels. International Journal of Remote Sensing (in review).

Kang, S., D. Lee, J. Lee, S.W. Running. Topographic and Climatic Controls of Forest Hydro-Ecological Processes in a Rugged Temperate Hardwood Forest in Korea. Agricultural and Forest Meteorology (in review).

Kang, S., J.S. Kimball, S.W. Running. Simulating effects of fire disturbance and climate change on regional forest productivity and evapotranspiration in boreal ecosystems. Global Change Biology (in review).

Presentations

1. Sinkyu Kang, Steve W. Running, Jong-Hwan Lim, Maosheng Zhao, Chandra Park. A Regional Phenology Model for Detecting Onset of Greenness in Temperate Mixed Forests, Korea: An Application of MODIS Leaf Area Index (LAI). A paper presented at MODIS Vegetation Workshop held in Missoula, MT, USA in July 16-18, 2002.
2. Sinkyu Kang, Steve W. Running, Rama Nemani, Maosheng Zhao. A Comparison Study between MOD17A2 PSN and Biome-BGC Prediction. A paper presented at MODIS Vegetation Workshop held in Missoula, MT, USA in July 16-18, 2002.
3. Sinkyu Kang, Maosheng Zhao, Steve W. Running. Cloud Filing of Mod17A2 Photosynthetic Product (PSN). A paper presented at VIII INTECOL Meeting held in Seoul, Korea in August 11-18, 2002.
4. Sinkyu Kang, Dowon Lee, Steve W. Running. Prospectiveness of modeling and MODIS data to predict effects of climatic variability on long-term carbon sequestration in a mixed hardwood forest. A paper presented at VIII INTECOL Meeting held in Seoul, Korea in August 11-18, 2002.
5. Sinkyu Kang and NTSG members. MODIS GPP and NPP Multiscale Monitoring for the Pacific Rim: Linkages with Tower Flux Network Measurements. A paper presented at Circum-Pacific Workshop held in Honolulu, HI in October 15-17, 2002.
6. Kang, S., J.S. Kimball, S.W. Running, A. Michaelis, M. Zhao. Comparisons of MODIS productivity and potential productivity in Pacific Northwest and BOREAS area. A paper presented at 2002 fall AGU Meeting held in San Francisco, CA in December 5-10, 2002.

7. Sinkyu Kang and NTSG members. Monitoring local and global vegetation productivity using Moderate Imaging Spectrometer (MODIS). A paper presented at the 88th ESA Meeting held in Savannah, GA in August 3-8, 2003.
8. Sinkyu Kang, John S. Kimball, Faith Ann Heinsch, Maosheng Zhao, Steve W. Running. Monitoring and predicting terrestrial hydro-ecological processes using MODIS and BIOME-BGC, and its application to arctic ecosystems. An invited lecture given in IARC, Fairbanks, AL in August 11-18, 2003.

Meetings attended

MODIS Vegetation workshop, Missoula, MT, USA for July 14-18, 2002
VIII INTECOL meeting, Seoul, Korea for August 11-18, 2002
Circum-Pacific Workshop, Honolulu, HI, USA for October 15-17, 2002
2002 fall AGU Meeting, San Francisco, CA for December 5-10, 2002.
The 88th ESA Meeting held in Savannah, GA in August 3-8, 2003.

ACTIVITIES OF M. Reeves (Ph.D. Student)

Activities of the last six months include manuscript preparation and teaching two MODIS workshops. I have been working on three manuscripts. The first, entitled "Usefulness and limits of MODIS GPP estimates for predicting wheat yield" summarizes a years worth of research on using MODIS gross and net primary productivity estimates for estimating wheat yield in Montana and North Dakota. MODIS GPP estimates can reliably be used as a tool for estimating state level wheat yields. However, the standard MODIS GPP estimates should not be used in conjunction with MODIS landcover for estimating county or climate district level wheat yield (Fig 1).

$r^2 = 0.35$

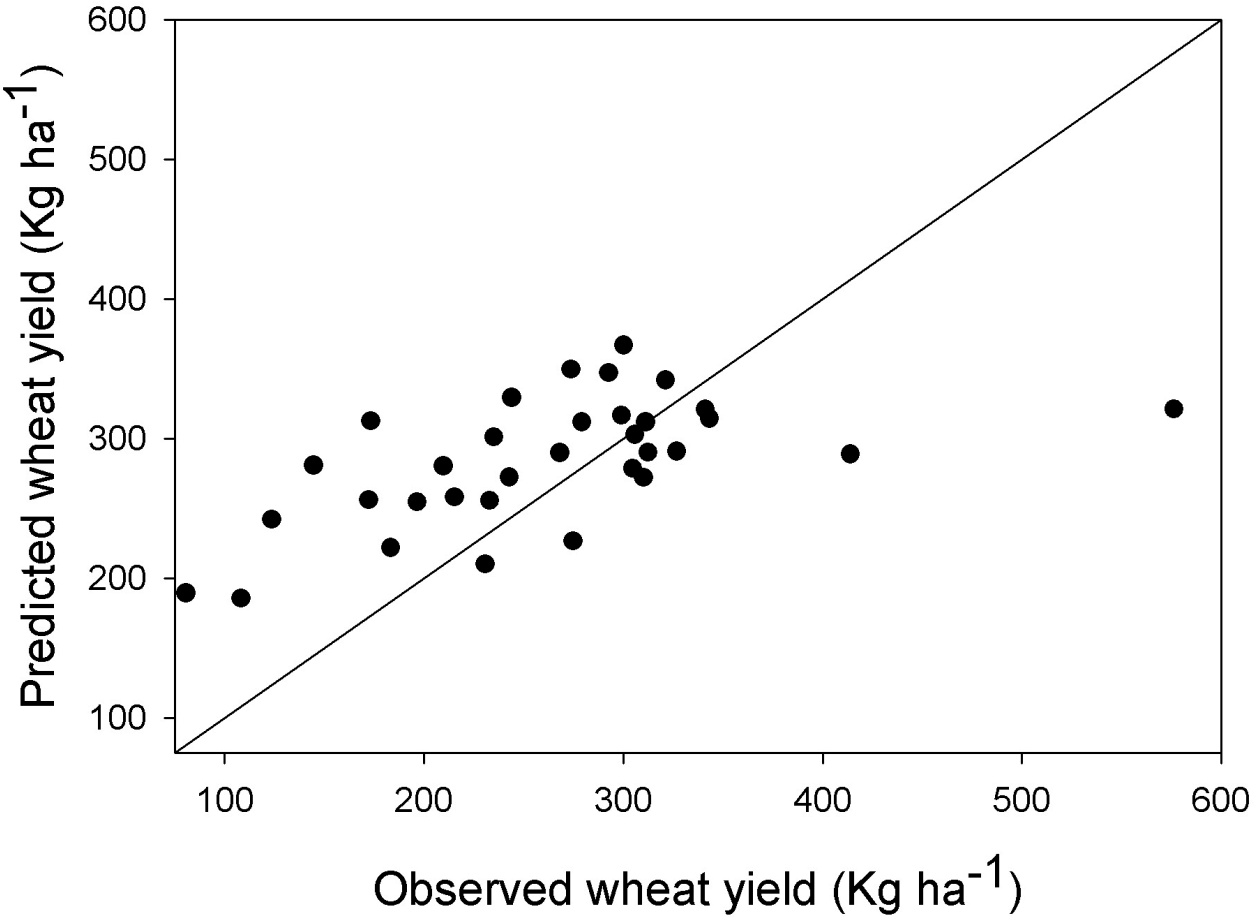


Fig 1. Relationship between predicted and observed wheat yield for counties of Montana with greater than 12,000 ha of planted wheat in 2001.

This is because MODIS land cover does not differentiate crop types and therefore adds significant noise to the analysis. MODIS GPP estimates can and should be used in a wheat yield algorithm that partitions carbon to grain based on phenological stage, especially with the aid of a more crop specific analysis mask. The second manuscript entitled "Combining meteorological and MODIS GPP data with knowledge of farming practices for improved estimates of wheat yield". This paper expands on the first to overcome the stated limitations. These improvements include a user defined mask of dryland agriculture for the area of interest, a phenomenologically oriented growth stage program, and a grain yield subroutine that relies on growth stage, temperature, and drought stress to allocate sequestered carbon to grain. These changes greatly improve our ability to predict wheat yield using MODIS GPP (Figure 2).

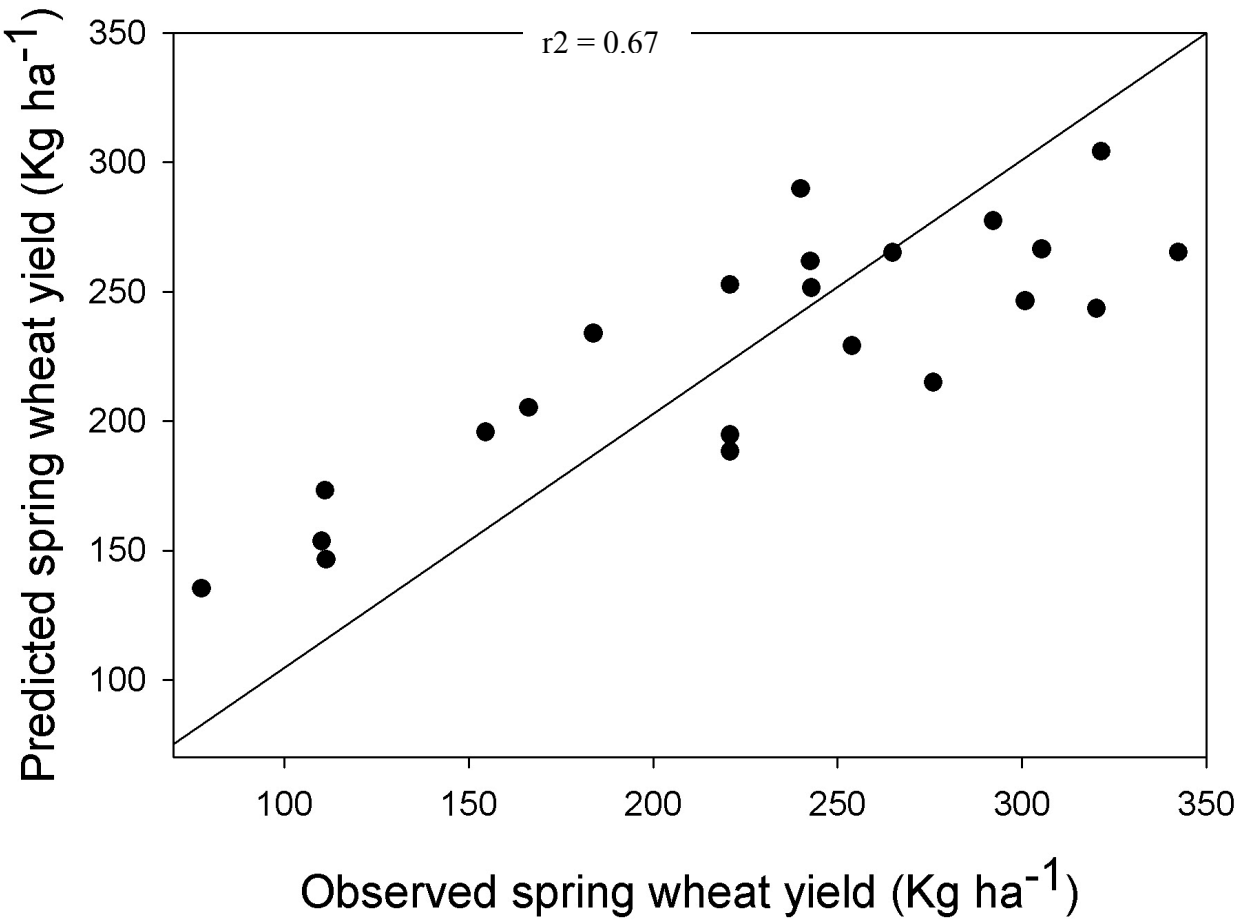


Fig.2. Relationship between predicted spring wheat yield for Montana counties derived from MODIS GPP estimates and observed yield. Points represent Montana counties where >12,000 ha of spring wheat was grown in 2001.

The third paper is entitled "Characterizing moisture driven rangeland biomass fluctuations using MODIS primary productivity estimates". The major thrust of this paper is to demonstrate the usefulness of MODIS productivity estimates for monitoring rangeland vegetation dynamics, particularly in response to moisture stress. Moisture stress in this paper is computed as stress is stress [DOY-1] + nPPT – nEpot where stressis the stress for the day, stress [DOY-1] is stress from the previous day, nPPT is normalized PPT achieved by dividing the PPT by the annual Avg and nEpot is normalized Pet calculated as by dividing the current days potential evapotranspiration by the annual average at the site. MODIS GPP estimates are more tightly coupled with observed vegetation productivity the NPP across all moisture stress regimes within the study area (Fig 3).

A

Fig. 3. Relationship between MODIS GPP estimates and peak of green (6 July, 2001) and above ground herbaceous biomass on the Northern Great Plains. Points represent mean observed biomass across a zone of meteorological influence established through creation of Thiesson polygons around weather stations located within the study area.

MODIS Workshops

I was a co-instructor with Dr. Dave Verbyla (University of Alaska Fairbanks) at two MODIS workshops. The first workshop was held in Missoula Montana 18 April, 2003. There were 28 participants. The workshop provided an overview of MODIS land products and included a half-day tutorial covering ordering, understanding and applying MODIS land products. The second workshop was held in Anchorage, Alaska at the American Society for Photogrammetry and Remote Sensing annual meeting 6 May, 2003. This workshop was nearly identical to the Missoula workshop, but covered specific topics from a scientific perspective more rigorously.

Activities of Cristina Milesi (PhD candidate)

Terrestrial net primary productivity (NPP), the energy base of all the trophic levels on the land surface, is the biospheric variable that probably has the most direct relevance to humankind. Yet, this variable has never been analyzed in conjunction with the distribution of human population.

This study analyzes the global distribution of human population with both the 1982-1999 average NPP and climatic constraints on vegetation growth. It also estimates the number of people living in areas where vegetation productivity was significantly correlated with ENSO (El Niño-Southern Oscillation)-induced climatic variability for the same period.
Half of the global human population is presently living in areas with above-average NPP, ranging from 410 to 760 g C m^{-2} $year^{-1}$. On average, the NPP over almost 40% of the total vegetated land surface has shown significant correlations with ENSO-induced climate variability, and, in 1998, more than a third of the global population inhabited these areas. The number of people living in regions suffering a decline in NPP was almost twice the population of regions showing an increase in NPP.

Future societal changes, either through demographic growth or migration, are expected to lower the NPP of the regions with highest productivity, which currently are sparsely populated. Even in the absence of an intensification of climatic extremes, population growth could increase societies' sensitivity to interannual variability in NPP.
As we continue to improve our understanding of climatic teleconnections and their effect on NPP, enhancing our ability of seasonal or annual forecasting, it is important that we keep monitoring human population dynamics. As longer time series of standard global NPP estimates from the MODIS EOS program will become available, this monitoring activity will be highly simplified.

While NPP itself provides a very useful measure of human impact on the biosphere and of the effects of climatic variability on societies, future work should also include the translation of global NPP into variables holding a more tangible economic and societal meaning, such as crop yield and timber production.

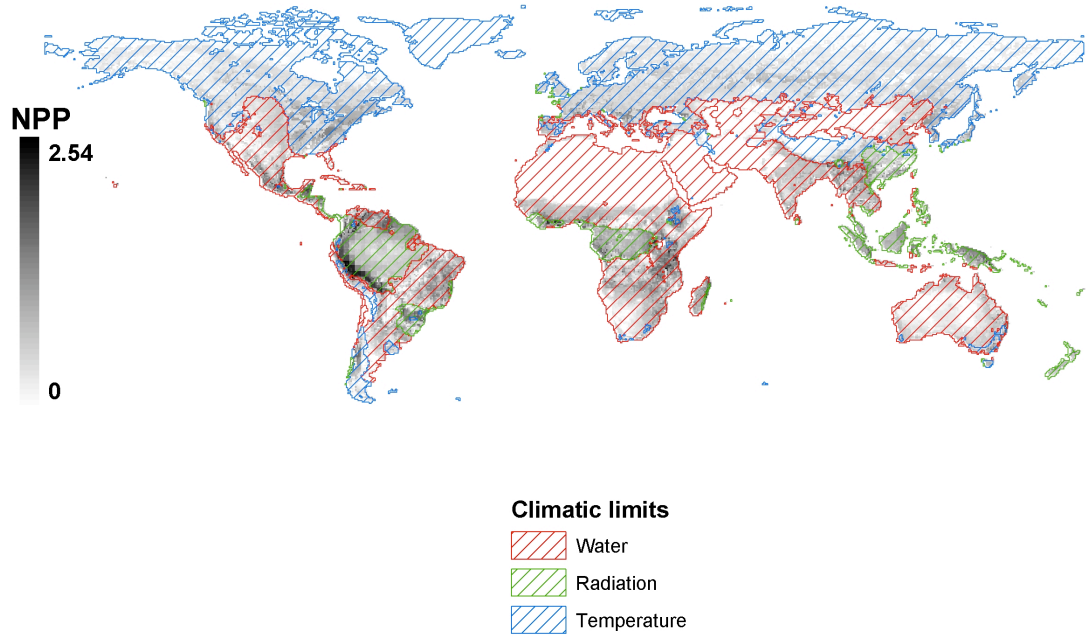


Figure 1. a) 1982-1999 average NPP at 0.5 by 0.5 degree spatial resolution; b) 1998 population derived from LandScan 1998. A map of the climatic limits on NPP is superimposed on both maps.

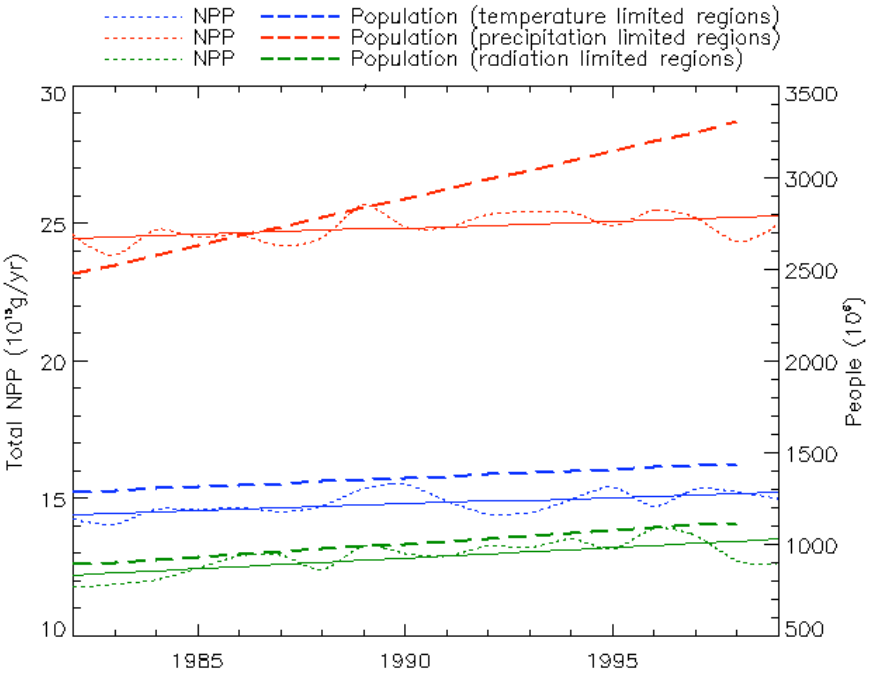


Figure 2. Times series of population (dashed line) and NPP (dotted line) for the period 1982-1999. The trend in NPP is superimposed on the NPP time series (continuous line).

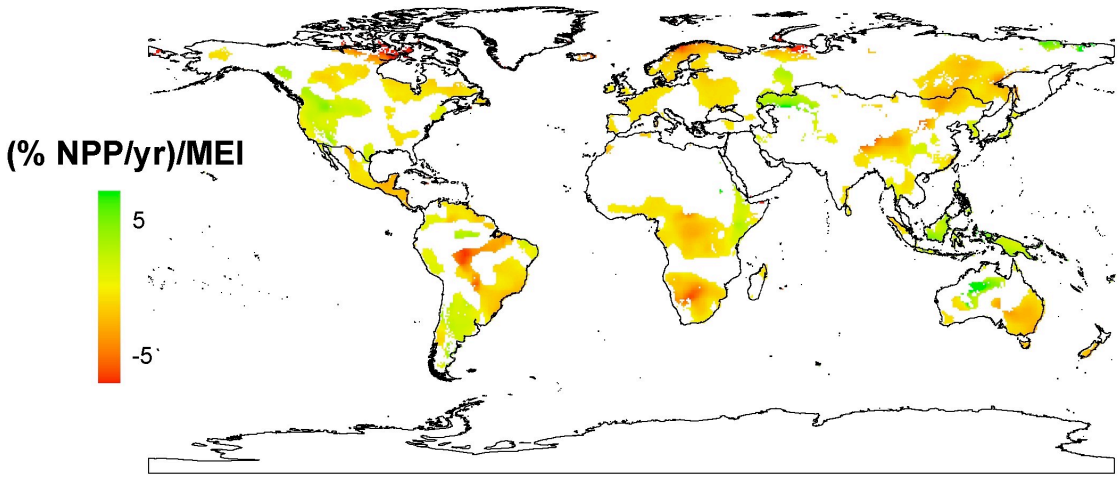


Figure 3. Significant correlations ($p<0.05$) between 1982-1999 monthly NPP and monthly MEI values.

Conferences attended:

2003 EGS - AGU - EUG Joint Assembly. Presented poster on: Assessing the populations at risk of variability in vegetation productivity

Publications:

C. Milesi, C.D. Elvidge, R. Nemani, S.W. Running. Simulated impacts of turf grass management practices on the carbon and water cycles of the United States. *Landscape Ecology* (In preparation)

C. Milesi, C.D. Elvidge, R.R. Nemani and S.W. Running. Synergistic use of MODIS and nighttime DMSP/OLS data for the study of urban environments. *Remote Sensing of Environment*. (In preparation).

C.Milesi, H. Hirofumi, R.R. Nemani and S.W. Running. A global analysis of the human population distribution in relation to terrestrial net primary productivity and its interannual variability. *Ambio*. (In preparation)

C. Milesi, C.D. Elvidge, R.R. Nemani and S.W. Running (2003) Impact of urban sprawl on net primary productivity in the Southeastern United States. *Remote Sensing of Environment*, 86: 401-410.

Activities of Rachel Loehman (PhD candidate)

The current project uses terrestrial net primary productivity (NPP) and gross primary productivity (GPP) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) to model risk of hantavirus pulmonary syndrome (HPS) in the continental United States. HPS is caused by viruses from the genus *Hantavirus*, family B*unyiviridae*, and is transmitted to humans through inhalation of excreta from infected rodents. The goal of the project is to develop an empirical model of the relationships between vegetation productivity, climate, and changes in reservoir population density, including any upper or lower limits to population growth and especially focusing on temporal lags between observed weather trends, biomass accumulation, and rodent population variability. The model is developed using monthly rodent trapping data from a selection of sites across the western United States, available weather station and DAO weather data, and MODIS 8-day NPP and GPP (NetPSN). Trapping sites are located within a diversity of biomes and across a range of elevations in order to capture ecologically and geographically specific responses in reservoir populations to changes in temperature, precipitation, and vegetation biomass. At this time rodent data from trapping webs are being acquired, and MODIS Collection 4 data are downloaded as they become available and subset to a 3x3 kernal surrounding each trapping site. During the coming year I expect to fully develop the model for specific trapping sites, and use the empirical relationships extrapolate to larger regions.

ACTIVITIES OF P. Votava, Lead Software Engineer, 1/03 – 7/03

OBJECTIVES

The objectives during the time period July 2002 to July 2003 are summarized here, with details on each of the indicated activity areas following.

- Patch our existing production code for Collection 3 reprocessing
- Prepare all our production code for Collection 4 reprocessing
- Oversee and troubleshoot MODAPS production of our biophysical land product suite.
- Perform ad-hoc Quality Assurance/Quality Control activities on our set of MODIS data products.
- Refine our SCF procedures and architecture using early MODIS product experience.
- Augment the MODAPS production team efforts by implementing selected SCF production scenarios required to supply NASA collaborators with early PR materials
- Continue to develop our MODIS/Aqua production code
- Continue development on the TOPS project

WORK ACCOMPLISHED

On the MODIS front, we have focused our efforts mainly at troubleshooting of our at launch algorithms, and at monitoring of the production of our products in the MODIS Adaptive Processing System (MODAPS). As a part of the troubleshooting, we have implemented number of Quality Control and Quality Assurance procedures. Additionally, we have introduced significant changes to all our algorithms that will produce much better results during the Collection 4 reprocessing that will start in December 2002.

Key accomplishments internal to the SCF for this period are further automation of procedures for PR image production, including reprojection, tiling, and sub-sampling. Additionally, we have improved our in-house software for our internal QA procedures with capabilities missing in all externally available tools. Most of this process is now database driven and the overall design uses a set of plug-in filters. Finally, we have produced global, local, and regional images of our MODIS PSN data for all the periods of 2001, 2002 and available periods of 2003 – this was done at 3 different resolutions. We have significantly upgraded our MODIS image Web site where all of these images are posted, and added database back end to this web site.

In TOPS we have significantly improved our prototype by improving the database design and started integration with the Automated Planner from Dr. Golden at NASA Ames.

ALGORITHM DEVELOPMENT

FPAR, LAI Daily and 8-day Composite (PGE33, PGE34)

The main science logic in the daily and 8-day FPAR, LAI has been stable for quite some time, with the changes in Collection 3 algorithm during this period mostly applying to minor

engineering issues pertaining to QA handling and ECS metadata interpretation. Additionally, new version of PGE34 (v4.0.3) for Collection 4 has been delivered. Last, three more patch deliveries has been made dealing with metadata issues and solar angle handling in the RT method.

I have implemented major changes that are required for Collection 4 reprocessing – this includes changing the SCF QA in our of our algorithms, changing the landcover used in daily FPAR/LAI (PGE33) from static IGBP at-launch landcover to a new MODIS-derived landcover, changing the strategy for compositing of our 8-day FPAR/LAI (PGE34) and implementing scientific changes related to high LAI values during saturation for biomes 1 through 4. Finally, we have changed the projection of the output data from integerized sinusoidal (ISIN) to sinusoidal (SIN).

I have also started working on a prototype of a combined Terra/Aqua product that should go into production in second half of 2004, and on global Climate Modeling Grid (CMG) that should be in production in the second quarter of 2004.

The daily FPAR, LAI algorithm (PGE33) is currently at version v4.0.11, for Collection 4 and is built using the SDPTK v5.2, HDFEOS 3.2, HDF 4.1r3, and MUM v.2.5.5 libraries. This algorithm is now at 18,723 LOC (77,095 LOC total includes the MUM API). The Collection 4 algorithm went through 4 science tests and is at version 4.0.11. This algorithm has been in production in both forward and backward processing as of 12/20/2002.

The 8-day FPAR, LAI algorithm (PGE34) is currently at version v4.0.3 for Collection 4, and is built using the SDPTK v5.2, HDFEOS 3.2, HDF 4.1r3, and MUM v.2.5.5 libraries. This algorithm is now at 10,198 LOC (70,043 LOC total includes the MUM API). Collection 4 algorithm has been in production in both forward and backward processing as of 12/20/02.

PSN, NPP (PGE36, PGE37, PGE38) Algorithm

The PSN, NPP biophysical algorithm (ESDT: MOD17A1, A2, A3) is unique among the other MODIS Land algorithms in the degree to which it is a model oriented rather than instrument radiometry oriented process. It requires daily availability of the new DAO DAS subset of global surface climatology variables, as well as the FPAR, LAI 8-day composite tiles from the most recent period relative to the day, the MOD12Q1 landcover definition, and its static ancillary data. The single most critical factor that sets the PSN, NPP algorithm apart from the others its temporal sensitivity, driven by the way that cumulative (additive) state variables for GPP, GPP minus maintenance respiration, maximum leaf mass and annual sum of maintenance respiration are carried forward throughout the year. From a production standpoint, delivering a temporally reliable stream of FPAR, LAI data to the daily PSN, NPP algorithm has become one of the most challenging, quality limiting aspects of the MODAPS. In the larger MODIS Land processing stream, persistent production gap problems arising in the EDOS portion of the ground system have propagated tile and time drop-outs of the MODAGAGG to the daily FPAR, LAI processing. These in turn are reflected in drop-outs of 8-day MOD15A2 to the daily PSN algorithm. While corrections to EDOS problems are reportedly on their way, to run our PSN,

NPP algorithm reliably, our SCF has had to locally stage up the required inputs, to implement limited processing here. We were able to implement a distributed production system and we were able to produce global annual products in a matter of a single day. The architecture uses Perl with thread support and distributes the processing across a 16-node Linux cluster. The runtime for global annual products (365 days x 288 tiles = over 100,000 tiles of data) is 22 hours.

There have been several major changes in the Collection 4 code to improve it from the current version. First, we have changed the QA to reflect the changes in the upstream FPAR/LAI product, additionally the QA of the yearly NPP has been simplified and corrected. Next we have fixed several bugs in the metadata and the science dealing with the DAO unit conversion. We have also added a new SDS to our 8-day product so that both GPP and PSN are generated every 8 days. Finally, there is a new lookup table (BPLUT) that significantly improves the quality of both PSN and NPP data. An external change introduced into the Collection 4 processing is the change of the climate data from DAO that transitions from GEOS3 to GEOS4 – the impact of this change will be analyzed as the Collection 4 data become available in 2003.

The PSN, NPP algorithm (PGE36, 37, 38) are currently at version 4.2.0 for Collection 4, built using the SDPTK v5.2, HDFEOS 3.2, HDF 4.1r3, and MUM v.2.5.8 libraries. The PSN, NPP algorithm is now at 18037 LOC (78,093 LOC total includes the MUM API).
The Collection 4 has been used in the production from 12/20/02.

TOPS

There are ongoing improvements of our framework prototype involving addition the Automated Reasoning Front End with Dr. Golden at NASA Ames. Other improvements include implementation of about 10 different modules including all the TOPS required modules, several visualization packages, and a MODIS PSN/NPP prototype. The prototype of the entire TOPS system should be ready in January 2003 and we will be ready to start daily-automated forecasts.

SCF DEVELOPMENT

Incremental additions to the Montana SCF were made during this period to increase our ability to perform high volume QA, test, and limited production in support of our global validation program.

Linux Cluster Development and Implementation

In last several months we have geared up to do several processing campaigns that involved our Linux clusters. The development of the cluster and automation software has spanned several versions. We have now completed the move from collection of Perl and shell scripts towards an integrated Java environment that gives us more control in the distributed environment. We have refined our Java client/server model to implement the distribution of tasks among the hosts in the cluster. One of the advantages of this approach is that we have removed the limitation of running

the distributed environment only on Linux hosts – the Java portability should allow us to operate in truly heterogeneous environment.

UM SCF Cluster and Processing Development

We have currently implemented distributed cluster servers to run both the FPAR, LAI 8-day (PGE34) and PSN daily, 8-day, and annual (PGE36, 37, 38). On the client side we have a new version of PGE34 client and scheduler that implements a simple load balancing scheme. Additionally, we have added our global PR (reprojection, mosaicing, subsampling, and imaging) system to run on our distributed environment as well. This system has been used in runs that produced our latest PSN composites. A similar system was used to produce our global 8-day PSN composite, which is quite bit more complicated. In the latter case, we needed to perform around 5,000 tile executions using the PGE. On current Linux cluster this required ca 4 hours to complete. In the next version, we plan on implementing a better graphical user interface for our system and to unify the Java/RMI environment. The initial step of each processing campaign starts with a PCF (runtime input command set) generation step is now part of the distributed environment and is done in Java. Finally, we have integrated our production algorithms with the Java distributed system, which helps us to maintain unified API across many different algorithms, and thus enables us to do much faster integration and more efficient scheduling.

COLLABORATIONS: SCIENCE AND DATA SYSTEMS

During this period the following collaborations were pursued for MODIS and TOPS related activities:

- Continued to closely collaborate with the Boston University staff on the refinements to QA procedures and interpretation of MOD15A1 and MOD15A2.
- We initiated an interim scheme to locally archive data products (MOD15A2 and MOD17A2), in support of our on-going Quality Assurance program, via periodic downloads from the MODAPS production environment. We are also archiving the following products: MOD09, MOD11A2, MOD43B3, MOD12Q1, MOD13A2
- Collaboration with Dr. Keith Golden at NASA Ames on the Automated reasoning front end of the tops project
- Collaboration with Dr. Steve Minton at Fetch/UCS on the execution environment of the TOPS project

CONFERENCES/MEETINGS

- NASA Modis Science Team Meeting, July 2002
- NASA IDU Workshop, September 2002
- AGU Fall Meeting, December 2002
- The 9th Scandinavian Research Conference on Geographical Information Science (ScanGIS), June 2003

- 7th International Symposium on Artificial Intelligence, Robotics and Automation in Space (ISAIRAS),

TALKS

- *Java Distributed Application Framework (JDAF)* at MST, 2002
- *Distributed Application Framework for Earth-Science Data Processing* at IGARSS'02
- *Parallelization of Earth Science Applications* at NASA IDU Workshop 2002

POSTERS

- *Biospheric Forecasting* Nemani, R, White, M, Votava, P. IGARSS'02
- *Forcing of 1982-1997 Ecosystem Water and Carbon Fluxes in the Conterminous United States: Relative Influence of Vegetation Structure and Phenology Versus Climate*, White, M A, Nemani, R R, Votava, P. AGU 2002.
- *Terrestrial Observation and Prediction System: Integration of satellite and surface weather observations with ecosystem models*, Nemani, R R, Votava, P, Roads, J, White, M, Thornton, P, Coughlan, J. AGU 2002.
- *Distributed Application Framework for Earth Science Data Processing*. Votava, P, Nemani, R, Michaelis, A, Neuschwander, A, Coughlan, J, Bowker, C. AGU 2002.

PAPERS

Votava, P., Nemani, R.R., Golden, K., Cooke, D., Hernandez, H., Ma, C. 2003. *"Parallel Distributed Application Framework for Earth Science Data Processing"*. In proceedings of The 9th Scandinavian Research Conference of Geographical Information Science (ScanGIS), Espoo, Finland, June 4-6, 2003.

Votava, P., Nanjo, S., Minton, S. 2003. "*Web Services for Distributed Earth Science Data Processing*". Accepted to the International Society for Optical Engineering (SPIE) Remote Sensing Europe, Barcelona, Spain, September 8-12, 2003.

Golden, K., Pang, W., Nemani, R.R., Votava, P. 2003. "*Automating the Processing of Earth Observation Data"*. In proceedings of the 7th International Symposium on Artificial Intelligence, Robotics and Automation in Space (ISAIRAS), Nara, Japan, May 19-23, 2003.

P. Votava et al, 2002. *Distributed Application Framework for Earth-Science Data Processing*. In proceedings of IGARSS 2002. June 2002. Toronto, Canada.

Myneni et al., "*Global products of vegetation leaf area and fraction absorbed PAR from year one of MODIS data*." Remote Sensing Environment, 83: 214 –231, 2002

Compute Services Team (CST)

Saxon Holbrook, Compute Service Team Manager (CST) & Network Administrator

Related Activities:

- ESIP Federation Activities: Represented NTSG as a voting proxy for the ESIP Federation Meeting January 6-9, 2003 in Pasadena, CA. Participated in multiple breakout and hands on training sessions and presented a poster **High-ResNPP.ppt** *file in this folder*. I'm an active member of the Constitution and Bylaws Committee, the Working Group for Peer Review and I regularly participate in the MODIS Cluster and ESTO Cluster.
- Managed day-to-day activities and projects of the CST. CST Members during this period: Chad Bowker (Data Manager, Contract Ended June 1, 2003), Andrew Neuschwander (Linux System Admin), Andy Michaelis (Student Programmer), Doug Wissenbach (Student Programmer, Graduated May 2003)
- Participated in specification and planning meetings for DAO investigation, Images website, Lupine Logic projects, etc.
- Completed installation and configuration of video conferencing solution for increased participation and reduced costs of participation in ESIP related activities.
- Completed overhaul of NTSG Website prior to Science Article release.
- Managed Software Environment and Licenses required for all activities.
- Data Legato Backup and Restores of online & near online MODIS Data.
- Managed and optimized network. Monitored Abilene I2 connection to EDC & Goddard.
- Prepared and Submitted Metrics to the ESIP Federation.
- Managed Windows Workstation and AIX Compute Environments.
- Maintained the DAYMET.org website. Preparing to transfer to P. Thornton at NCAR.

Meetings/Training attended:

- MODIS Vegetation workshop, Missoula, MT, July 14-18, 2002
- ArcGIS Training, Bozeman, MT, August 12-16, 2002
- ESIP Federation Meeting & Technical Workshops, Pasadena, CA, January 6-9, 2003

Individual CST member reports:

Chad Bowker (Data Manager, Programmer)

Tasks Accomplished:

Prototype of the web interface to NTSG Data Warehouse.
Data filters for meteorological data.
Data download automation for meteorological data.
Work on aspects of the JDAF framework.
Retrieval and processing of MODIS data for EOS Ed website.
Automation of processing of MODIS data for EOS Ed website.
Negotiation of data subscription with the Snow and Ice Data Center.
Negotiation of data subscription with the Land Processes Data Center.

Current and Ongoing tasks:

Acquisition and management of MODIS and other EOS datasets.
Monitoring of NTSG Data Warehouse to ensure data integrity and compliance of metadata to NTSG, ESIP Federation and NASA guidelines/standards.
Participation in automation of data retrieval and dissemination system.
SEEDS liaison.
Maintaining the MODIS Vegetation Workshop website help desk.

Recently attended Conferences:

HDF EOS Conference, Greenbelt Maryland.
MODIS Vegetation Workshop, Missoula Montana.
SEEDS Second Workshop, San Diego California.
ECHO Training Session, Greenbelt Maryland.

HDF-EOS Conference highlights:

At the HDF-EOS conference we were exposed to several budding new technologies as well as new ideas about old ones. We were able to glean a better understanding through hands on tutorials of the HDF-EOS data format. We also met some collegues who were interested in our activities. This conference also gave us an avenue to get some feed back from the broader user community on what needs are not being met in data availability and data services.

SEEDS Second Workshop:

The SEEDS group promises to be the new standards entity for NASA's Earth Science Enterprise. By attending the workshop we have a good idea of where NTSG will fit in and where we can be of the most use to the SEEDS group. While at the workshop I was able to participate in some of the breakout groups, giving me a good understanding of where the community is, and where it is headed in the future. Of paramount concern at the Conference was the lack of representation by the scientific user community. NTSG would be able to be a key voice for the science community at SEEDS.

ECHO training Session:

The ECHO training session helped to enlighten NTSG as to this new service. NTSG is eager to participate in this developing technology in order to better facilitate our data services to our users. Using ECHO we will be able to reach an even broader user base than we currently have, and with ECHO's close ties with SEEDS we will be able to grow into the future together. We have decided to write a data provider interface to ECHO to make our metadata available, with the possibility of writing a client interface in the future.

Co Authored Papers:

Votava, P., R. Nemani, C. Bowker, A. Michaelis, A. Neuschwander, J. Coughlan. 2002. "Distributed Application Framework for Earth-Science Data Processing". In Proceedings of IEEE IGARSS 2002, Toronto, Canada

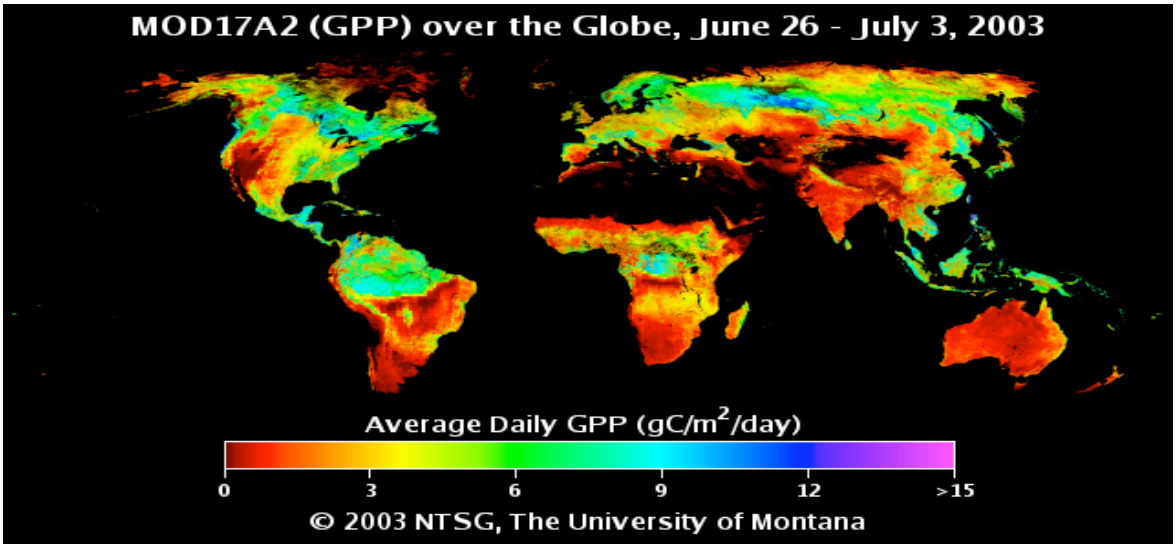
Andrew Neuschwander (LINUX System Administrator)

Data Mangement

- Now Manage: approx: 5TB of Data.
- Took over Data Management. Brought the Lab up to date on various data sets:
    - MODIS (selected products) Up to date MOD15/MOD17 from MODAPS.
    - NCDC Daily Summary, Global Surface Observations used in SOGS for Hi-Resolution GPP/NPP (complete mirror).
    - NRIS GIS data (partial mirror)
    - ORNL MODIS ASCII Subsets (complete mirror).
- Deployed a new version of data tracking database. Led student intern (Doug) in design and development of a database/file system synchronization tool.

NTSG Images: http://images.ntsg.umt.edu

- Led the redesign and update of the Images Website. Worked closely with LLI.
- Finished work (along with Andy) on the Modis Image tools. These include tools to mosaic, reproject, convert, and annotate images of MODIS Data. Led Doug (student intern) in design and development of database scheduler/planner for image generation.



Other Projects & Tasks

- Developed prototype histogram tool for MOD17 by Land Cover. Wrote detailed specification and delivered to LLI for implementation.
- Provided highly optimized toosl (compiler/blas/atlas) for sogs.
- Continued to support the Compute Clusters
- Continued to support Core lab IT services: web/email/ftp, etc.

Meetings Attended

- MODIS Vegetation workshop, Missoula, MT, USA, July 14-18, 2002
- ESIP Federation 2nd Technical Workshop, Pasadena, CA, USA, January 2-8, 2003
    - Sessions Included: MODster, GeoTIFF, MapServer, WCS, WMS, Open Source Software, Data Mining, Earth Science Markup Language, and the Earth Science

Data Service.

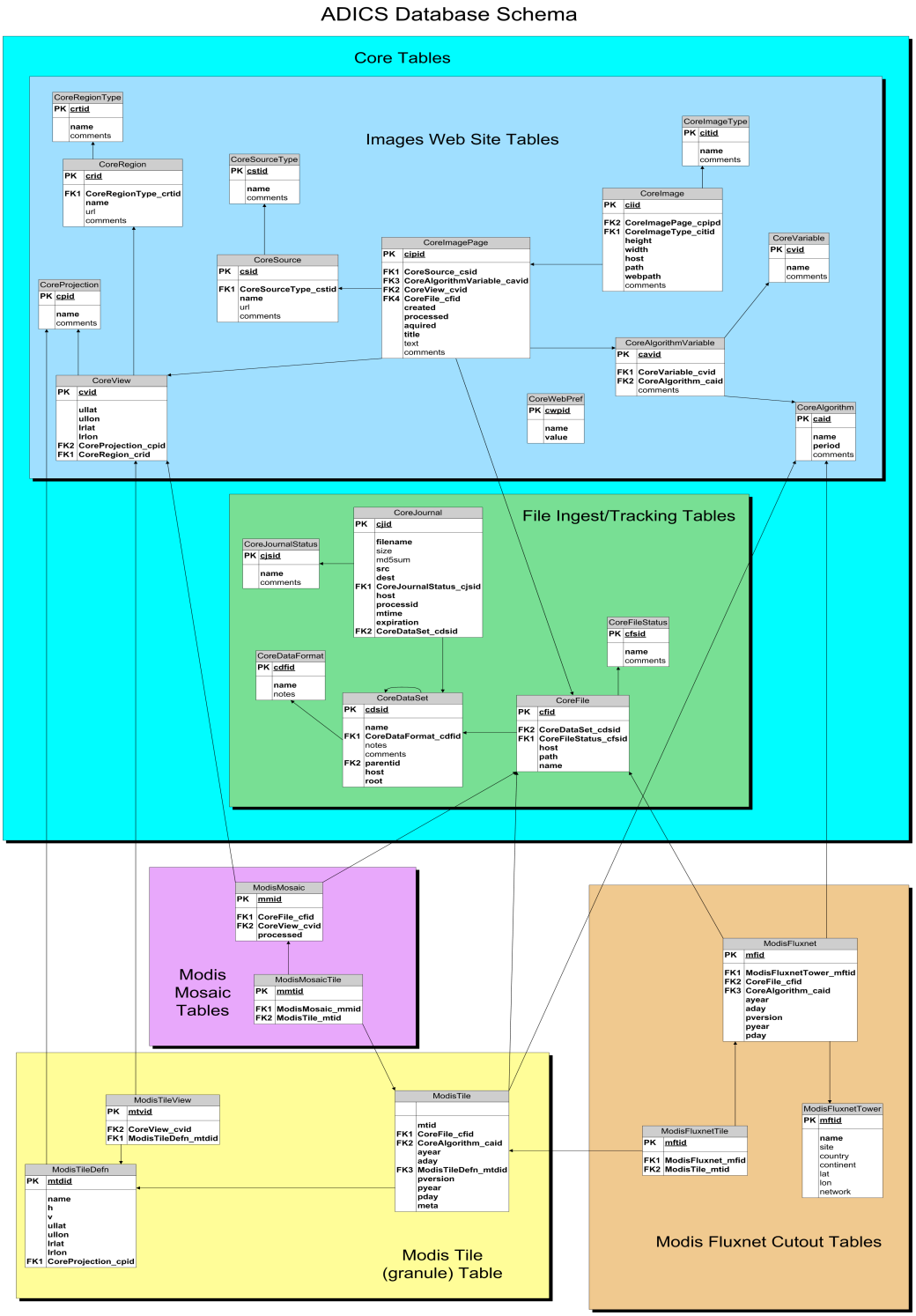


Figure: ADICS Database Schema

Activities of Andrew Michaelis (student developer)

A summary of activities for the past six months will be partitioned into four sections. Section one discusses the current progress and future goals of the Surface Observation Gridding System from a developer's perspective. The second section gives a brief summary of activities regarding the "in house" MODIS imagery tools used to create images for the NTSG website. Section three is a summary of the work concerning a distributed BIOME BGC, and finally section four is miscellaneous notes, meetings attended, etc.

Surface Observation Gridding System (SOGS)

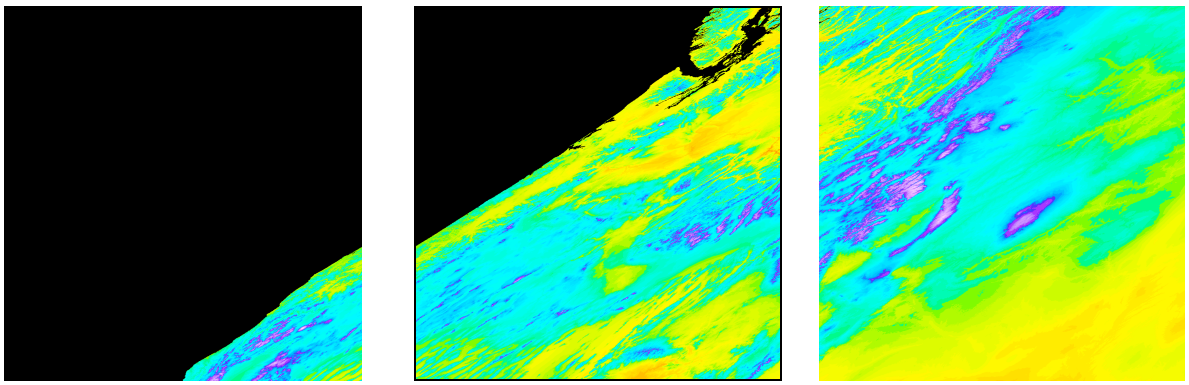
The Surface Observation Gridding System aims to generate meteorological surfaces from readily available surface observation data. Observational point source data is ingested into a spatial database from multiple sources, such as NCDC and CPC, via the Internet on a routinely basis. Shortly after the data has been acquired, a mathematical processor and or interpolator may use it to generated meteorological surfaces on demand.

Currently the system retrieves and stores NCDC data when it becomes available. Our current NCDC point source data holdings are from 1994 to present, which may be used to generate surfaces over any region of reasonable resolution and grid size. In the near future CPC and SNOTEL data will be ingested regularly as to enhance the database and perhaps the gridded surfaces.

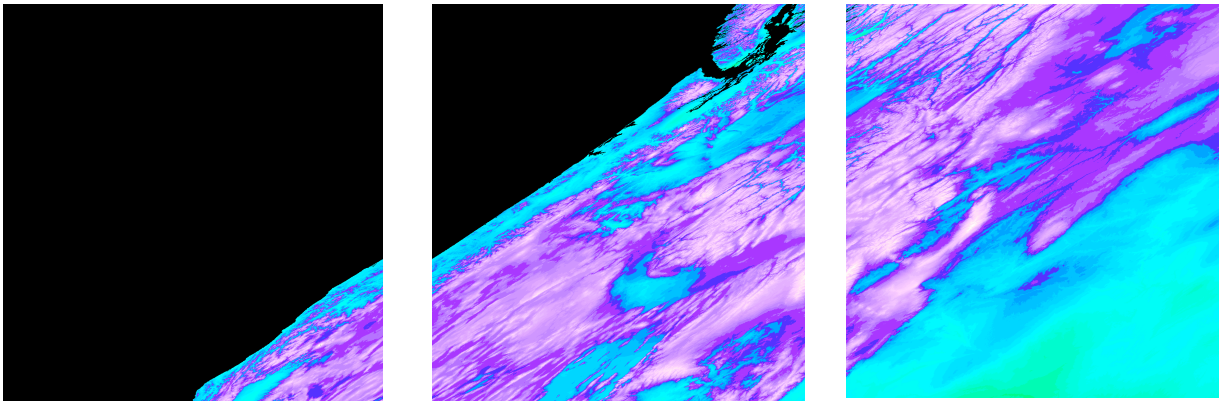
The mathematical interpolators the system currently provides are ordinary kriging [1] and a truncated Gaussian filter [2]. Solar radiation and vapor pressure deficit are estimated using the methods suggested by Dr Thornton [2]. When higher resolutions outputs are preferred, the system allows for one incorporate slope and aspect terrain information, if so desired, which may improve results. This past six months we have worked relentlessly to optimization these interpolation and processing routines in order to allow for the generation of finer resolution surfaces (<= 1km) within a reasonable amount time.

It should be noted that custom surface resolutions and regions of interest are easily generated. The system provides a variety of output file formats: HDFEOS, ASCII Text and raw binary. The HDFEOS output format is similar to the MODIS output format so a user familiar with the handling of a MODIS "tile" will find the data easy to access and utilize.

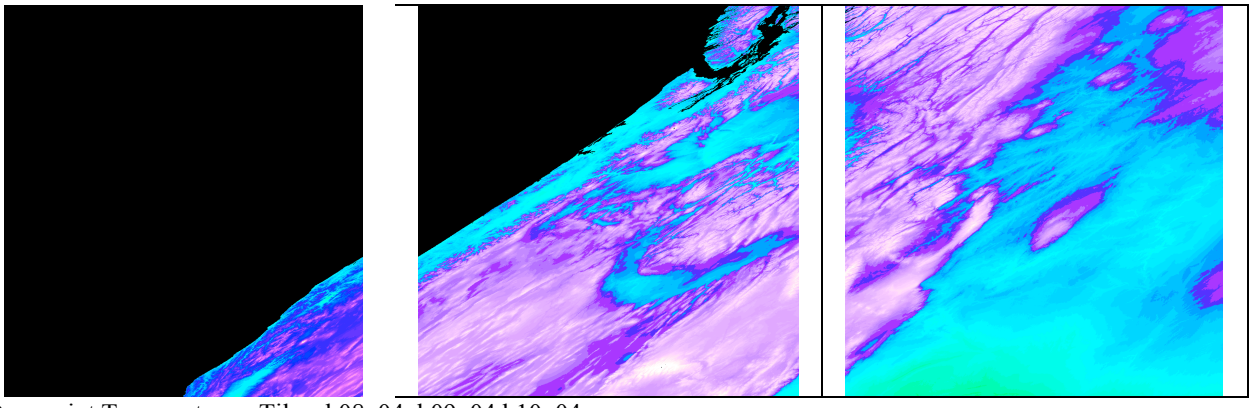
Below are examples from April 29 2003 in a sinusoidal 1km grid (Extracted from HDFEOS file).



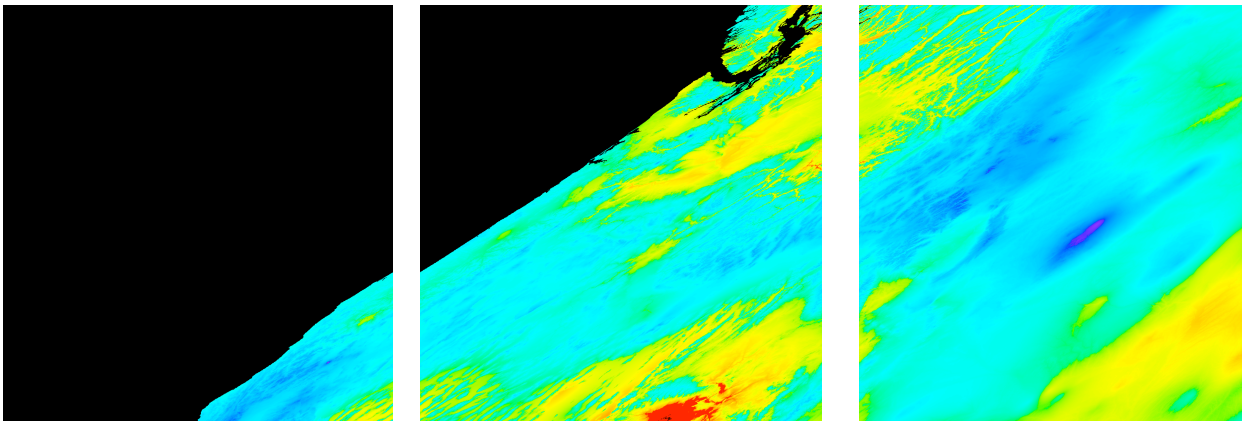
Maximum Temperature. Tiles: h08v04, h09v04 h10v04 all images prepared by Andrew Neuschwander, NTSG



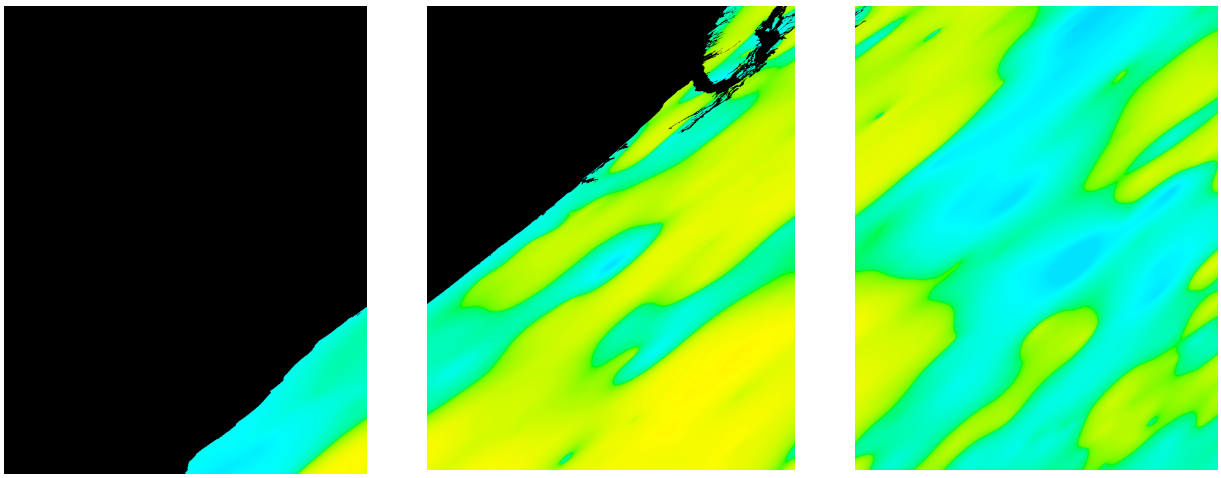
Minimum Temperature. Tiles: h08v04, h09v04 h10v04



Dew point Temperatures. Tiles: h08v04, h09v04 h10v04



Vapor Pressure deficient. Tiles: h08v04, h09v04 h10v04



Solar Radiation, slope and aspect terrain information was used in estimating surfaces. Tiles: h08v04, h09v04 10v04

In the future, a user friendly website may be created to make this data accessible to those who would require meteorological surfaces for modeling ecological processes.

MODIS Imagery Tools

I have been an active member in updating and maintaining the lower level API in the reprojecting, mosaicing and image creating utilities. These utilities are used to generate MODIS images for the NTSG website. This past six months we (Computer Service Team) have made updates and enhancements that allow these tools to handle a variety of MODIS products with increase output options; the enhancements are reflected on the NTSG website.

Distributed BIOME-BGC

Large-scale gridded BIOME-BGC simulations can require a considerable amount of time to execute. I have constructed a BIOME-BGC "wrapper" utility that allows one to distribute this application on *n* nodes, which may significantly decrease execution times. This "wrapper" has been successfully tested and has allowed Dr. kang (NTSG) to perform many simulations in a significantly short time period.

Miscellaneous Activities

Meetings attended:

1. ESIP Federation Technical Workshop, Pasadena, CA 2-8 January 2003
2. MODIS Vegetation workshop, Missoula, MT 14-18 July 2002

Presentations:

1. Jolly, M. A. Michaelis. Surface Observation Gridding System poster. Presented at ESIP Federation meeting, Pasadena, CA January 2-8, 2003

Presentations and Papers I have been associated with:

1. William M. Jolly, J. M. Graham, A. Michaelis, R. Nemani1, and S. W. Running "A flexible, integrated system for projecting meteorological surfaces derived from point sources across multiple geographic scales" (In preparation)

2. Kang, S., J.S. Kimball, S.W. Running, A. Michaelis, M. Zhao. Comparisons of MODIS productivity and potential productivity in Pacific Northwest and BOREAS area. Presented at AGU Meeting held in San Francisco, CA December 5-10, 2002.

3. Votava, P., R. Nemani, A. Michaelis, K. Golden. 2002. "Distributed Application Framework for Earth-Science Data Processing Terrestrial Observation and Prediction System Case Study". American Geophysical Union (AGU) Fall 2002 Meeting. San Francisco, CA.

4. Votava, P., R. Nemani, C. Bowker, A. Michaelis, A. Neuschwander, J. Coughlan. 2002. "Distributed Application Framework for Earth-Science Data Processing". In Proceedings of IEEE IGARSS 2002, Toronto, Canada

References:

1. Issaks, E. H. and Srivastava, R. M. (1989). An Introduction to applied Geostatistics. Oxford University Press, New York

2. P.E. Thornton, S.W. Running and M.A. White, Generating surfaces of daily meteorological variables over large regions of complex terrain, J. Hydrology, vol. 190, pp.214-251.

Activities of Lupine Logic, Inc (LLI) J.M.Glassy, Jeff Norman, and Casey Gerstle

on contract to Univ. Montana NTSG NASA MODIS Land SCF
January 2003 to July 2003

OBJECTIVES

Key LLI objectives during this period are identical to our objectives for the previous semi-annual report period, which are to:

- Contribute both development and user support for the legacy NTSG algorithms, MOD15A1, MOD15A2, and MOD17A1,A2,A3, including editing and contributed sections of the new PSN, NPP User Guide document.
- Participate in troubleshooting and support of the heritage Terra NTSG biophysical land algorithms (daily FPAR, LAI, 8-day FPAR, LAI, daily, 8-day PSN, and annual NPP).
- Contribute design and implementation consulting for the ADICS image catalog system, for acquiring, managing, and displaying MODIS derived imagery on the NTSG web site.
- Evaluate ongoing algorithm design issues involving a simplified Aqua MODIS EI algorithm in development, and monitor Aqua instrument status and integration sequence of up-stream algorithm data products required by MYD16A1 and A2.
- Coordinate algorithm support with Petr Votava and NTSG CST group on local SCF production of selected University of Montana MODIS land products for in-house evaluation. Primarily the 8-day PSN, and annual NPP algorithms.
- Contribute to the on-going effect to identify and resolve any remaining software defects in the University of Montana Terra platform land algorithms.

WORK ACCOMPLISHED

During this period we have performed the following tasks and accomplishments, divided into legacy Terra algorithm support, Aqua ET algorithm development, and contributed software to the ADICS image catalog system.

Legacy Terra UM land algorithm support

Effort during this period on the legacy University of Montana NTSG NASA MODIS algorithms has focused on modifications required to produce new Collection 4 generation codes. The PGE 36,37,38 suite (PSN, NPP data products) have been the primary focus on these refinement and re-delivery efforts. Lupine Logic, Inc. staff has continued to work closely with NTSG staff (Maosheng Zhao, Rama Nemani and others), and Petr Votava in NASA AMES to refine these codes. In terms of overall PSN, NPP product quality, the quality has improved a number of SCF analyses have now been performed, which have resulted in the identification and correction of several code defects which had diminished PSN and NPP data product quality for prior code generations.

A key contribution by LLI in this period for supporting legacy Terra algorithms was contributed work on the PSN, NPP User Guide.

Aqua ET Algorithm development

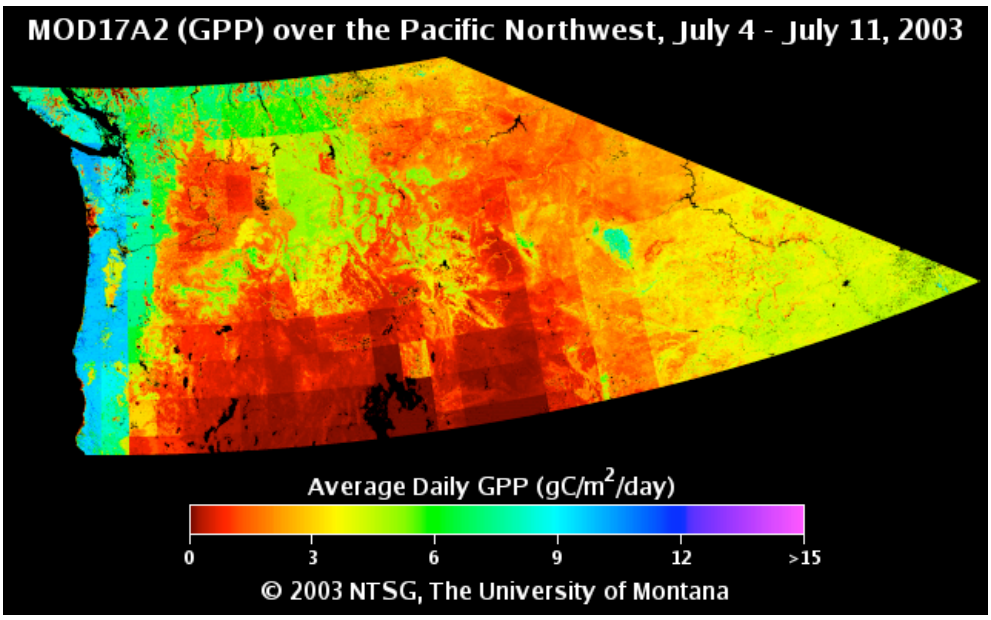
During this period, Aqua ET algorithm development (MDY16A1, A2 as PGE77, 78) has undergone a fundamental feasibility review, with potential major changes studied in order to simplify the processing logic from the original sliding 20x20 window (convolution filter approach) approach to a pixel-independent approach more structurally similar to that used on FPAR, LAI and PSN algorithm suite. Dr. Running working with colleagues in Australia led this analysis, assisted by

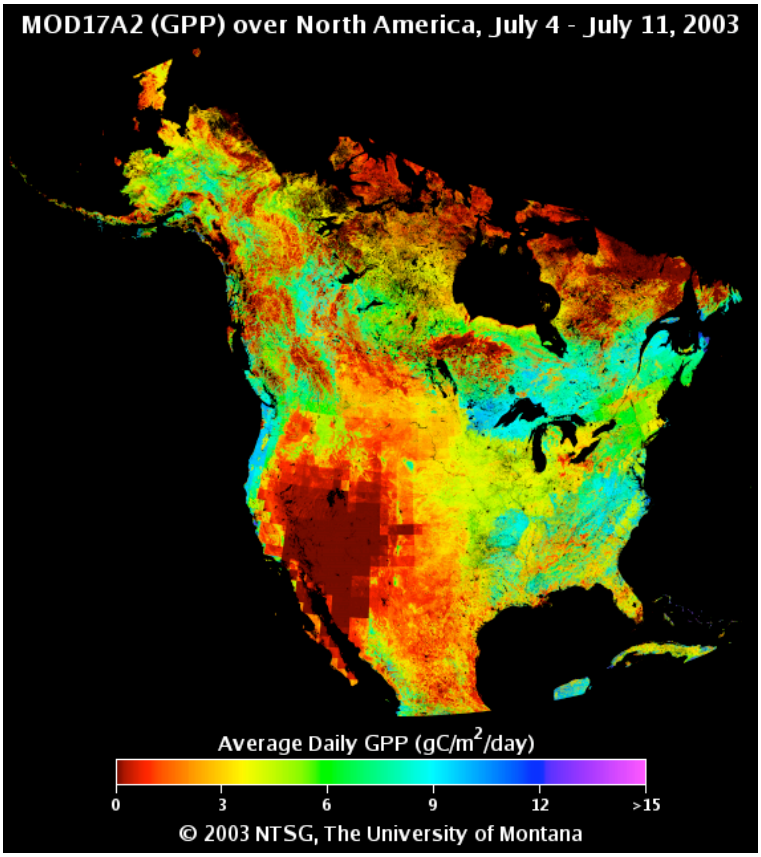
ADICS Image Catalog Development

LLI staff Jeff Norman and Casey Gerstle contributed a variety of software development effort to the ADICS Image Catalog system at the NTSG. (http://images.ntsg.umt.edu) The goal of the ADICS system is to present and display selected MODIS derived imagery stored in the NTSG data warehouse to the public. Both browse and search functionality is included in this image catalog facility, implemented primarily using postgreSQL and PHP scripting. Approximately 4500 lines of code where developed for the system. A news item database was developed with an administrative interface to allow control of the news items for the website.

The content emphasis for the NTSG image catalog facility thus far have been the Gross Primary Production (GPP) product derived from the land MOD17A2 algorithm. Key benefits offered by the image catalog presentation of GPP and follow on products are that the system provides an automated generation/presentation and display pipeline, with biophysical value scaling (in the legend) and label and date-time annotation on the PNG images. These images are provided in this way to give users a data-reduced view of the content, not analytical content. A separate effort is in the works to selectively provide georeferenced imagery in its analytical (biophysical variable) form.

Recent examples of this imagery, supplied as PNG files, are shown below:





COLLABORATIONS

- Dr. Petr Votava – participated in on-going collaboration in the refinement of MODIS SCF algorithms for local and MODAPS ECS processing throughout the period.
- LLI has continued contact with a variety of NTSG staff, MODIS PI's, and sub-teams during this period, troubleshooting algorithm performance, assisting developing code patches, and tracking progress of the Collection 4 and anticipated Collection 5 processing stream and changes.

MEETINGS ATTENDED

MODIS Coordination and ad-hoc planning meetings between NTSG and LLI have been held approximately bi-monthly at the University of Montana NTSG office during this period.